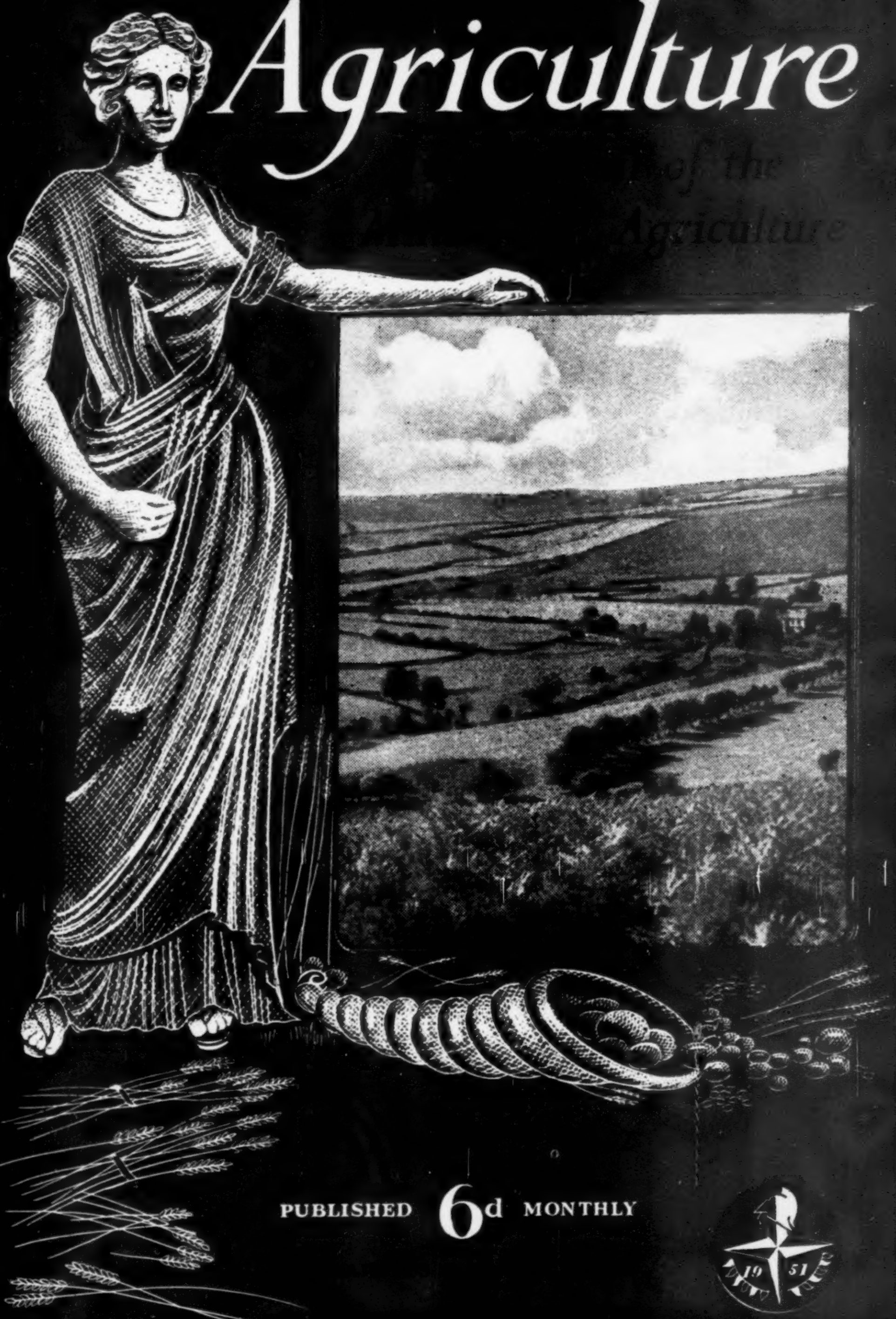
BRITAIN NUMBER

May 1951

Agriculture



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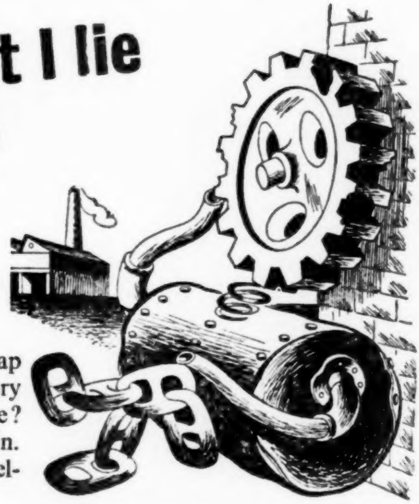

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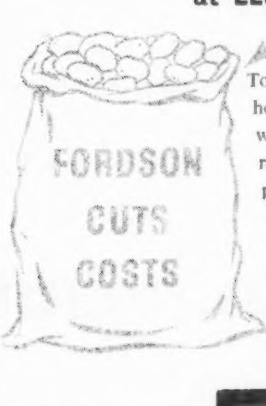

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VOL. LVIII No. 2 MAY 1951

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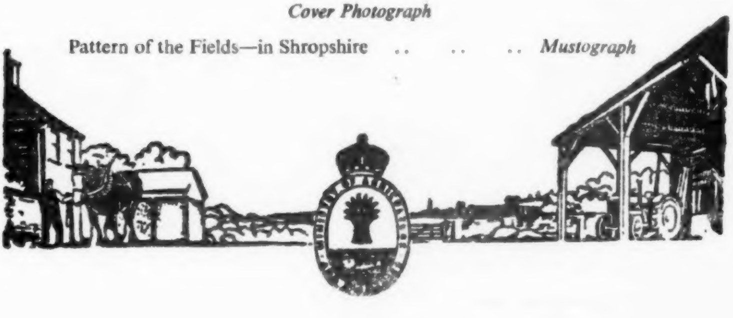
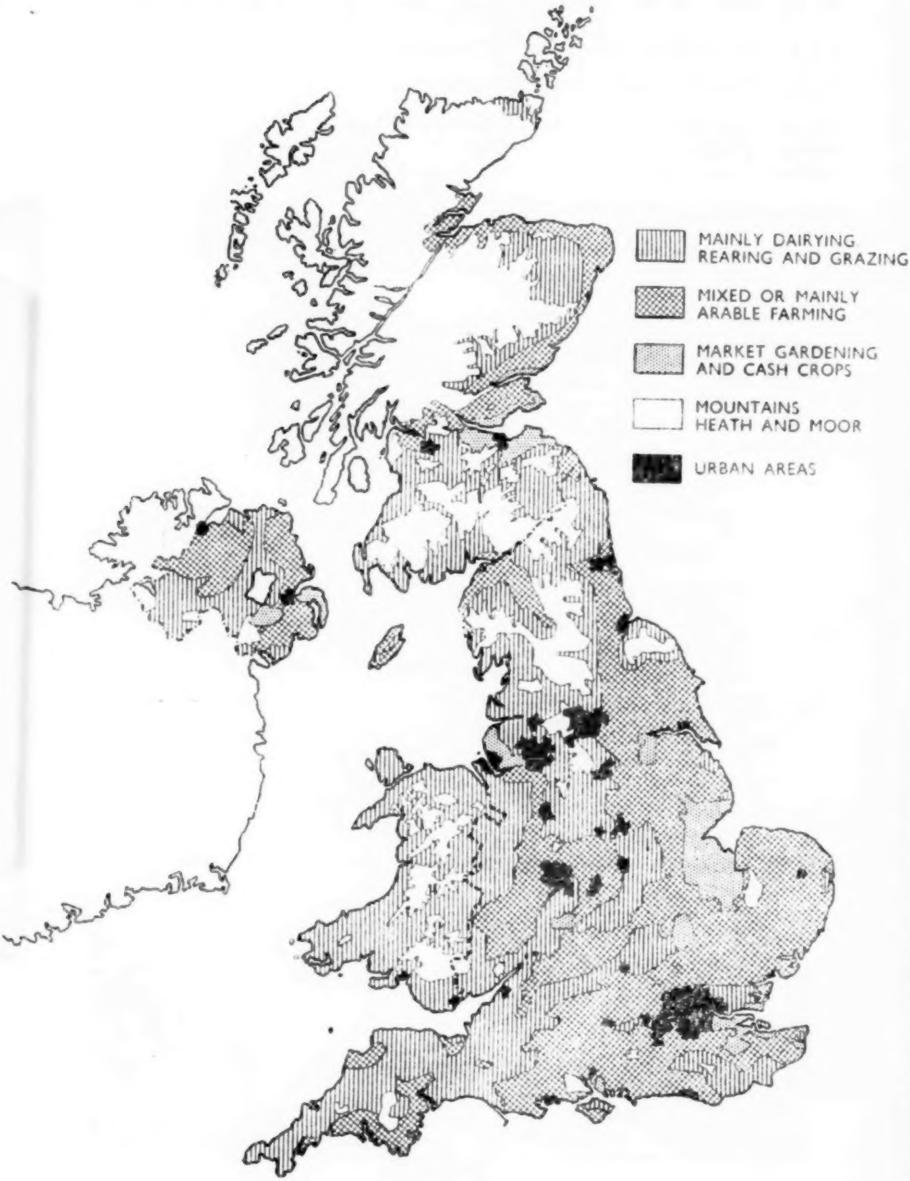


Types of Farming in the United Kingdom



Total area :	**59,552,926 acres**
Total agricultural area :	**48,229,130 acres**

AGRICULTURE

THE JOURNAL OF THE MINISTRY OF AGRICULTURE

VOL. LVIII No. 2 MAY 1951

THE EVOLUTION OF FARMING IN BRITAIN

FROM EARLIEST TIMES TO THE MID-NINETEENTH CENTURY

C. S. ORWIN, M.A., D.Litt.

To appreciate fully the developments of Britain's agriculture from a subsistence level to the highly organized industry that it is today, they must be seen against the backcloth of history. In the following article Dr. C. S. Orwin traces the main influences which have shaped their course.

PRIMITIVE man the world over was a hunter not a farmer. He depended upon the natural products of the soil for sustenance: fruits, roots, birds, animals, fish and insects, and their produce, such as eggs and honey. It may be assumed that Britain conformed to the general experience, but far back in pre-history there is evidence of the practice of primitive forms of soil cultivation and of the domestication of animals. Farming standards advanced from these beginnings as successive waves of invaders or colonists from the mainland of Europe landed at various points along the coast, and penetrated into the country. Just as Britain owes the foundation of her general culture to these continental influences, her language and religion, her art and literature, so it is easy to trace what we owe to them in early days for technical progress, including the practice of husbandry. Southern England was growing corn, and possibly exporting it, before Caesar landed, and it is likely that the introduction of the mouldboard plough which the Romans used had anticipated his coming. Certainly we owe to settlers who came from western Europe the system of land tenure, expressed in the common cultivation of the soil by village communities, which has been practised by farmers of almost every race and clime, and in some countries right up to the present day.

The Open Fields and the Manorial System The pattern of farming as it emerged from the Dark Ages was the open-field system, with the principles of which most people are familiar. Land was occupied by small village communities, who cultivated it by a sort of co-operative organization of labour, each man contributing in one way or another to the make-up and work of communal plough teams. The number of them depended upon the size of the community. Each day's work was allotted in rotation to the men participating in the common task, and thus was produced the system of individual holdings scattered in strips around the village, each representing a day's work with one of the joint ploughs. Experience showed that the extent of cultivation possible during the dead season of the year with each plough sufficed to give the co-partners in its work holdings of about 30 acres of ploughland each. There were different degrees of tenancy, however, and while some men might have had less, a few seem to have had more. Rotation farming was developed early ;

indeed the seasons may be said to have dictated it. Autumn-ploughed land had to be sown in the autumn, and land ploughed after Christmas was sown in the spring, which divided the village lands into two blocks, the autumn-sown and the spring-sown. Soon it came to be realized that continuous cropping left the land foul with weeds, and infertile. Where there was plenty of land suitable for cultivation and the community was small, the practice was to abandon it for a period of years, while nature restored it to condition, and to break up and cultivate fresh land. This system was followed in the wilder, hilly districts of Britain, sparsely populated, until comparatively recent times. In the more fertile plains, the practice developed of resting each of the cultivated areas once every three years, and the land of the village community came to be divided into three parts, farmed on a rotation of winter corn, spring corn, and bare fallow.

The rest of the land around the three open fields comprised wastes and woodlands, the virgin soil and natural vegetation of the country, ready for reclamation as the size of the community grew ; in the meantime it was available for grazing by livestock, particularly pigs. But the open fields themselves were valued sources of grazing. Extending as they might to hundreds of acres, they included steep and rough places which could not be cultivated, green roads to give access to the remoter strips and so on, all of which could add up to a considerable area. Above all, there were the stubbles after harvest. These provided good feed in the form of ears dropped in binding and carrying the sheaves, and in the crop of weeds which grew, no doubt, in plenty among the corn. Every farmer had the right to turn out cattle and sheep from the time the harvest was finished until an agreed date, after which ploughing for the next crop began. On the fallow field of the year, sheep were allowed to run, maintaining themselves as best they could on stubbles, weeds and the grass on the rough places until the time of the following autumn sowing.

Hay was made in the low-lying places, often beside streams and rivers, the mowing grass being allotted amongst the farmers in alternate strips representing a day's work with the scythe. This land, too, was thrown open when the hay had been carried, to provide grazing on the lattermath for the cattle of the community in common, until an agreed date in the autumn.

How far this system of land tenure and farming extended in England is not certain. Right up to the end of the eighteenth century, and later, there were still large areas of woodland and waste. In the hill country, too, there was little arable cultivation, while in some of the flat, fertile counties, enclosure of the open fields and farming in severalty was introduced so long ago that little evidence for it remains. By and large, however, it may be stated that the great bulk of the arable farming of the country was carried on at one time or another under this system. Obviously it was complicated, but for a thousand years or more it held its position as the form of land use by which the people were fed, and two things accounted for its permanence. In the first place, everyone was farming with one common object, self-supply, which produced a common technique. There was a common time-table, a common fund of knowledge, and everyone was doing the same thing at the same time. In the second place, the administration of the common arable fields and the grass commons was entirely in the hands of the people who occupied them. The rights and liabilities of every one of them were defined by well-established customs, enforced by a panel of the farmers themselves who had powers to punish those who offended against them.

The system of tenure was the Manorial System. The owner of the land, subject to the rights of the Crown, was the lord of the manor ; the status

of the tenants varied, but all were liable for service both on the manor court which controlled the farming system or as officers of the court, to secure the observance of its regulations. Strongly established before the Norman invasion, it held its own in most of the arable farming districts well into the eighteenth century.

The Beginnings of Commercial Farming The rigidity of the organization left little scope for individual choice in farm practice, but it was not until opportunities for cash farming arose (that is to say, production for a market as well as for self-supply), that the open field system raised any serious question. Almost every member of the village community produced the food, the wool and so forth which his family needed, and it was only around the few larger towns that anything approaching commercial farming was to be found, before the beginnings of industrialism and the development of a growing non-agricultural consumer class. Wool was the commodity to be first exploited for the market on any scale. As Lord Ernle has written, " Sheep were the sheet anchor of farming. But it was not for their mutton, or for their milk, or even for their skins that they were chiefly valued. Already the mediaeval agriculturist took his seat on the woolsack. As a marketable commodity, both at home and abroad, English long wool always commanded a price. To the Flemish weavers it was indispensable. . . ."*

The Black Death, that scourge which is said to have reduced the population of some parts of the country by nearly one-half in the middle of the fourteenth century, was another factor contributing to the development of sheep farming. The resulting scarcity of labour found the lords of the manors with much land thrown on their hands. Sheep farming on grassland called for little labour, and this encouraged a considerable enclosure movement, not only of wastes and grass commons but also of extensive tracts of arable strips in the big open fields themselves. Markets were established, some of them in this country, to which foreign wool buyers resorted, but more of them on the other side of the Channel, to which the English merchants conveyed their wool. So profitable was this trade that during the Tudor period, enclosure for sheep farming was developed without consideration for the small subsistence farmers. Thus Dr. W. G. Hoskins relates how, in 1495, Sir Ralph Shirley, in Leicestershire, converted so much arable land into pasture that " 30 persons departed in tears and have perished."†

These early enclosures of the open fields for farming in severalty affected principally the south Midlands. Not all of them were oppressive, nor are they notable for any improvement in the technique of crop production ; they are important, rather, as indicating the emergence of the business man in farming—the man who could seize the opportunity to make money out of the changing circumstances of his time. Enclosure gave such men the change to develop their individuality to the full, and it was upon the unenterprising and the thriftless that it bore hardly. There was high-handed action, of course, by the lords in some places, as they sought increased profits out of the wool trade by extending their farms, and it affected, doubtless, good and bad tenants alike. English farming, however, emerges at the end of the two centuries which finished with the Tudor dynasty, as being actively embarked upon commercial development in the principal districts affected

* Ernle, Lord. *English Farming Past and Present.* 5th Edition. 1936.

† Hoskins, W. G. *Essays in Leicestershire History.* 1950.

by enclosure, even though in hundreds of open-field manors the standard of performance remained generally low.

It was the growing needs of the market, no doubt, which induced the Government to survey the fenlands of the eastern counties and to set up an administrative system for them in the early years of the seventeenth century. This encouraged an association of the local landowners under the leadership of the fourth Earl of Bedford to contract with the famous Dutch engineer, Cornelius Vermuyden, for the drainage of a great area, the Bedford level. Ultimately nearly three-quarters of a million acres of this fertile land was reclaimed for farming.

The Agrarian Revolution The country, however, was on the eve of a great agricultural expansion, which, during the next two hundred years, was to bring about an economic and social revolution in its rural life. The Wars of the Roses, the Dissolution of the Monasteries and the increase of foreign trade, creating a wealthy mercantile class, had brought about extensive changes in the ownership and occupation of land. Land came on the market as never before, and a new landed aristocracy was created out of the rising middle classes seeking investment for the profits of trade and industry. Lord Ernle quotes a contemporary writer for the statement that in the first half of the seventeenth century, half the land of Staffordshire, for example, had changed hands.*

Enclosure was going on all this time, but now it was not so much for sheep grazing as for the practice of an improved mixed farming which could not be developed to the best advantage in the open fields. Landmarks in this improvement were the introduction of clovers and grasses into the rotation, and the cultivation of turnips on the fallow field. Travellers from the Low Countries had noted these crops and the benefits which followed their use in continental husbandry ; by degrees the old three-field rotation of wheat, spring corn and bare fallow began to give place to a four-course with clovers and grasses following the spring corn crop, and the bare fallow cropped with turnips. An immense increase in production was thus secured, but the new rotation could not be practised so long as common grazing of the stubbles was the custom. Thus enclosure received a great impetus, carried through at first by voluntary agreements and later by private Acts of Parliament. Between 1760 and 1815, upwards of 1,800 Acts were passed through Parliament for the enclosure of open arable fields and meadows, most of it in the midland and eastern counties. In Lincolnshire, for example, nearly half a million acres were enclosed, in Cheshire little more than three thousand, during these years. By 1850, the enclosure of the open fields everywhere was practically complete.

The effects of this great movement were considerable, both socially and industrially. There has been much controversy over the social consequences of enclosure, but the weight of evidence seems to indicate that they bore hardly upon the humbler sections of the ancient village communities. In them the landless labourer class was very small : nearly everyone had a direct interest of some kind in the land, even if it were nothing more than the right attached to the cottage in which he lived to graze geese on a common. Other wage workers would have a few strips of arable land in the open fields, which carried the right to turn out perhaps a score of sheep on the stubbles and the fallow. These rights, almost trivial in themselves, were the first rung in the ladder of social and economic advancement to the thrifty, leading by stages to the occupation in later life of an open-field farm sufficient to

* *Op. cit.* p. 85.

maintain the tenant and his family in full employment. An allotment of land upon enclosure was not necessarily an equivalent in the scope for mixed farming which it afforded, particularly for the maintenance of the livestock which had roamed the open fields ; and the little plot was generally transferred to a larger neighbour. The larger of the new enclosed farms could be staffed more economically, and in one way and another there arose that sharp division between the occupier of farming land and the wage-worker upon it, which characterized English agriculture in greater and greater degree from the eighteenth century onwards. The demand for labour became at once more seasonal and less in total. Some of the redundant labour was absorbed by urban industry ; in fact this was the only outlet for surplus rural labour until the opening up of new lands in other parts of the world a hundred years later. Those who remained to work for wages on the land lived in a state of poverty more or less chronic, a social problem which has been solved only during the present century.

There is no question, however, about the economic advantage to the country of the enclosure of the open fields, and the improvement of the enclosed holdings which followed, for the practice of farming by small capitalists working their land with hired labour. The ancient system of peasant farming on the basis of the family unit, which still characterizes all the older countries of the world, could not continue to satisfy a nation actively engaged in the expansion of urban industry, in which the demand for food from its non-agricultural element was increasing every year. The spread of industrialism throughout the eighteenth century, for example, synchronized with a great acceleration of technical progress in farming, but this was restricted to farmers of enclosed holdings, for in the open fields the pace of progress was the pace of the slowest. Notwithstanding all the foresight of the Manor Court for the control of the common fields and commons, and all the care of its officials in the enforcement of its bye-laws, the scabby sheep would turn up to spread disease, the ill-bred sire to thwart the livestock improver, the unenterprising neighbour who resisted changes in the rotation, and the laggard whose fences were not mended and whose ditches were not dug ; these handicaps could be obviated only on the enclosed farm, where the enterprising farmer controlled his own destiny.

The Agricultural Improvers The new rotation, with its addition to the hay crop, and above all its cropped fallow, revolutionized farming practice and immensely increased the productivity of farming. The additional fodder and the new root crops made it possible to carry livestock through the winter in numbers undreamt of under the old three-field rotation ; while the manure thus produced in yards and in folds raised the yield of the corn lands. Enclosed grazing of livestock encouraged the breeder to consider his standards with some hope of attaining improvement in weight and quality. Thus the eighteenth century was a time of steady progress alike by landowners and their tenants in the improvement of the farmer's art. The King, George III, followed farming with enthusiasm on the royal farms ; the greater landowners experimented with the new crops and processes for soil improvement and encouraged their tenants to profit by their experience. They, and even more, perhaps, the larger farmers, were responsible for the great strides in livestock improvement initiated in the first half of the eighteenth century, which have continued to the present day. Amongst cattle, the Longhorn predominated over a large part of the country, particularly in the Midlands ; it was this breed that first attracted the improver's attention, when a Derbyshire landowner, Sir Thomas Gresley, set about the selection of a herd bred for shape and

colour and milking qualities. He had a disciple in Warwickshire, a farmer named Webster, who in his turn inspired the best known of all the early livestock improvers, Robert Bakewell of Dishley, in Leicestershire. A farmer of outstanding quality, Bakewell raised himself to an unrivalled position by his work for the improvement of Longhorn cattle, Leicester sheep and the old English heavy horse. Today, the Longhorns have vanished, displaced everywhere by the Shorthorns, except for a fancy herd here and there, and the same is almost equally true in this country of the Leicester sheep. But Bakewell demonstrated to breeders of other stock what could be done in one man's lifetime by empirical methods to raise the quality of farm livestock.

Of equal importance was the improvement of soil fertility. From the days when fallowing was the only agent, farmers had learnt the value of composted animal and vegetable residues, and the application of lime and marl for certain soils, as restoratives of fertility. It was not until the beginning of the nineteenth century, however, that scientists began to examine the connection between soil conditions and plant growth. In 1793 Pitt's government had set up a Board of Agriculture and Internal Improvement, and ten years later this body appointed a distinguished chemist, Sir Humphrey Davy, as Professor of Agriculture to the Board. By his experimental work he laid the foundations of the study of agricultural chemistry, which, continued in Germany by Justus von Liebig, was brought to full fruition in this country by their brilliant successor, John Bennett Lawes, of Rothamsted.

All through the eighteenth century technical improvements in the processes of farming were going on, and these too received a great impetus in the early nineteenth century. The removal of surplus water from the soil had been an age-old problem, solved only, where surface conditions permitted, by ploughing up and down slopes. The disadvantage was that the finer soil particles were often washed away, and here and there local practices arose by which trenches were cut and the bottoms filled with stones or faggots before the top soil was replaced. Thus the water was removed by percolation into the trenches instead of by washing down the surface of the furrows. The problem was to find a satisfactory filling for the trenches, and it was not until 1843 that the invention of the cylindrical clay pipe resolved the difficulty of providing a water conduit which was both cheap and efficient.

The invention of machinery for the farm to lighten manual labour and to increase its output was increasing. Jethro Tull's horse hoe and seed drill were introduced at the beginning of the eighteenth century, but progress during the next hundred years was slow. The *caruca* of classical times differed little, except in the material of its construction, from the common English plough, and it was the invention of Patrick Bell's reaping machine in 1828 which may be said to date the beginning of the great advances made in the application of machinery to farming. Almost simultaneously, other labour-saving devices were being invented—threshing and winnowing machines, chaff and turnip cutters, and so on. Adoption of the new inventions was slow, and farm workers were suspicious of innovations which might reduce the demand for their labour. Threshing machines, in particular, provoked hostility, on the score that they tended to deprive the labourer of steady work with the flail upon the barn floor in the slack winter season, and rioting and rick-burning accompanied their introduction.

The earliest field machinery was operated, of course, by horse power ; stationary machinery, such as the threshing machine, and machines for

grinding, pulping and chaffing in the barn, were run by horse-gears, water-wheels and sometimes by wind power. Soon, however, the steam engine, long in use in manufacturing industry, was applied to agriculture ; at first its use was confined to the fixed machinery at the homestead, but by the middle of the century it had been extended to the cultivation of the soil. To John Fowler, of Leeds, belongs the credit of introducing the first successful steam ploughing tackle.

The evolution of farming technique during the eighteenth and early nineteenth centuries was rapid only by contrast with that which had preceded it. The great increase in consumer demand as manufacturing industry developed, and high prices during the long drawn-out Continental wars, had stimulated food production, but most of the means of publicity for innovations and improvements of all kinds available today, the agricultural shows, the breed societies, the agricultural press, were lacking. From 1778, that great landowner, Coke of Norfolk, had gathered together at Holkham an annual party of farmers to discuss agricultural topics and to inspect his land and stock. These Holkham " sheep shearings " developed into great gatherings attended by hundreds of persons from all over Great Britain, the Continent and America, and similar meetings were inaugurated by a few of the large landowners in other parts of the country. At Dishley, Bakewell had kept open house to display his improved livestock, and Colling's great Shorthorn, *The Durham Ox*, was carried all round England for exhibition. By the end of the eighteenth century, too, many local farmers' clubs and discussion societies had been started ; the *Farmers' Magazine* though now extinct, started on a long career in 1800. But the great network of agricultural shows, the agricultural journals, and even more, the breed societies, are developments of later date. The Board of Agriculture, already referred to, was short-lived, though the survey of agriculture, county by county, which it carried through when Arthur Young was its secretary, and his own publication, the *Annals of Agriculture*, have left a unique and invaluable record of farming in this country at the close of the eighteenth century.

The End of Protection Ever since the fourteenth century the export and import of corn had been regulated by Act of Parliament, though the maintenance of high prices for wheat and dear bread for long periods at the end of the eighteenth and in the early nineteenth centuries, were due to a variety of causes, such as bad harvests, a long Continental war, financial policy, and so on, even more than to the Corn Laws themselves. But the growing industrial population had come to regard them as a symbol of dear food. To the industrial capitalist, cheap food meant lower labour costs ; to the wage-worker, both industrial and agricultural, a fall in wheat prices represented a rise in real wages. The agitation for repeal of the Corn Laws was reinforced by a disastrous harvest in 1846 and the Irish potato famine, and in that year legislation giving effect to it was passed through Parliament. The old supremacy of the landed aristocracy in national administration had been challenged and broken, and for the next hundred years, British agriculture was to be carried on under a free-trade economy.

A CENTURY OF FARMING PROGRESS

PROFESSOR SIR JAMES A. SCOTT WATSON, C.B.E., LL.D.

Director-General, National Agricultural Advisory Service

Despite its economic ups and downs, the hundred years 1851–1951 emerges as an era of unparalleled progress in the history of British farming. Professor Sir James Scott Watson here takes up the story of British farming development from the year of the Great Exhibition.

THERE is an abundance of material from which to reconstruct the picture of our agriculture as it was a hundred years ago. The population of England and Wales was about 18 million, of whom just about one-half were townsfolk. The people's food (except only wheat, of which less than a quarter was imported) came substantially from our own farms, and our standard of farming, as M. Lavergne remarked after his extensive survey*, was " the best in the world, and in the way of realizing further progress."

The large-scale reclamation of heath and wold, moorland, marsh and fen, which had been proceeding steadily for three centuries, had almost been completed, while the great bulk of the old open fields and commons had been enclosed and laid out in separate farms. The main roads were fit to carry all kinds of traffic, and the network of railways, though the mesh was still wide, covered the whole land. In short, the broad pattern of the countryside, except that there was more corn and less grass, was very much as we know it today.

Although memories of the "hungry 'forties" and of the Irish Famine were still fresh in men's minds, the food position in 1851 was much improved. Indeed, the recent fall in corn prices seemed to justify the fears that had been engendered by the repeal of the Corn Laws five years earlier ; in the event, however, these fears proved to be premature. The expected flood of imported wheat was not destined to arrive for a generation.

Having almost exhausted the reserves of virgin soil, farmers were bent upon intensifying their methods, and many new resources had lately come to their aid. The greatest of the undertakings actually in progress during the year of the Great Exhibition was the tile drainage of the clays and other wet lands. The recent development of tile-making machines, and the prevailing low rates of winter wages, had reduced the cost of the operation to a figure of the order of £3 or £4 an acre, and drainage loans were on offer, upon reasonable terms, by a number of great land improvement companies. The substitution of under-drainage for the old ridge and furrow system had resulted, in not a few cases, in a doubling of yields.

A few more years were to pass before Rothamsted was to establish the basic principles of plant nutrition, and farmers were still groping for the right combination of muck, lime, bones and the new " portables "—Chilean nitrate, sulphate of ammonia from the new gas-works, Lawes's superphosphate and the almost miraculous Peruvian guano. But all these were being increasingly used.

Overseas visitors were filled with admiration for our farm implements, of which a comprehensive collection had been staged at the Great Exhibition.

* *The Rural Economy of England, Scotland and Ireland.* Translated from the French, with notes by a Scottish farmer, 1855.

The wide range of types, and the high standards of design and workmanship, were the outcome of the development of large factories, equipped with all the resources of engineering science, which were already catering for the overseas as well as for the home market. Portable steam engines and threshing machines were being produced at the rate of hundreds every year. For the home farmer the sensation of the exhibit was provided by the new American reaping machines.

The pattern of contemporary farming, with its emphasis on corn—and particularly on wheat—was imposed by current demand and prices. The artisans' families, during periods of full employment were, indeed, by this time consuming increased amounts of meat. But the level of employment fluctuated violently, and otherwise demand came almost exclusively from the well-to-do. Consumption of milk was beginning to rise, but was still very low by comparison with that of today. Bread and a little cheese, with a very occasional meat dinner, was the fare of the common labourer and his family in town and country alike. In the years about the turn of the century the price of wheat varied around 14s. a hundredweight, while meat and cheese were about 5d. a pound, and milk, at retail in the cities, was commonly 2d. a quart.

The main objective of the arable farmer—and the arable area was large—was to maintain as high a wheat acreage as was consistent with good husbandry. The actual acreage (in England and Wales) was probably about 3.4 millions.

Since rents were very high in relation to prices, and since farm labour was plentiful and wages low (about 10s. a week on the average) the efforts of farmers were concentrated upon higher yields per acre rather than bigger output per worker. Wheat was generally hand-hoed, beans were often dibbled by hand and, because employment on the land was far less in winter than in summer, a good deal of threshing was still done by flail. The intensive application of labour, with the use of the new fertilizers, the feeding of large quantities of oil-cake to yarded cattle and folded sheep, together with the introduction of improved crop varieties, had raised yields to a level that seemed incredible to visitors from overseas. James Caird* put the average yield of wheat at 26½ bushels (14 cwt.).

Among the farmers' enemies were most of those that are with us today—the turnip "fly," clover sickness, club-root of turnips, potato blight, cereal mildews, bunt of wheat, and more. Drainage and enclosure had greatly reduced the incidence of liver rot and of sheep scab, but the past dozen years had seen the arrival, presumably from overseas, of foot-and-mouth, pleuro-pneumonia and sheep-pox.

"The Golden Age" Later generations were to look back upon the third quarter of the nineteenth century as a period of great prosperity—as indeed it was by comparison with the times which followed. Perhaps historians have painted the picture in rather too rosy hues. The corn country, from Northumberland to Essex and Dorset, was prosperous indeed, but elsewhere there is little evidence that even the large farmer drove his carriage-and-pair, or often broke a bottle of wine for dinner. However this may be, the period was one of unexampled progress. New discoveries and inventions followed each other in rapid succession ; and even more remarkable was the rate at which each in turn was generally applied. The fact was that there had been a strong revival of interest in farming among

* *English Agriculture in* 1850–51.

the educated classes, from the great landowners and their agents to the squires and the larger tenants. Almost typically the landlord, with his agent, played the role that now falls to the Advisory Officer, and many a home farm was a demonstration and experimental centre. The Journals of the Great Societies were widely read and the national agricultural press—*Bell's Messenger* and the *Agricultural Gazette*—attained a high standard. Discussion societies, from the Farmers' Club downwards, flourished, and shows, ploughing matches and other such events drew large crowds.

It is here possible to note only the major steps of development. In respect of mechanization, the new reapers quickly came into general use and were improved stage by stage—self-delivery, side-delivery and finally the string binder—which last, however, was to bring with it the long-dreaded mass imports of prairie wheat. In 1858 John Fowler was awarded the "Royal's" £500 prize for his steam-ploughing tackle, and in a few years' time the "steamer" became a familiar sight in areas of large-scale arable farming. Cultivators, haymaking machinery and other things were steadily improved.

By 1855 it was possible to draw firm conclusions from the Rothamsted experiments, and to put fertilizer usage on a rational basis. The "major" plant nutrients were phosphate and potash for all crops, with nitrogen for all except the legumes. Moreover, it had been demonstrated that a tolerable level of production could be maintained, over a period of years, by means of "artificials" alone. Usage of nitrogen and phosphates steadily rose and, from the early 'sixties onwards, ample supplies of potash became available from the new Stassfurt mines. The results from the last, on some of the lighter soils, were phenomenal.

In respect of livestock, the major handicap to progress was the growing incidence of cattle disease. Contagious abortion, foot-and-mouth and pleuro-pneumonia each took a heavy toll. But the great disaster was the epidemic of rinderpest in 1865–66. By February, losses had reached a figure of about ten thousand head a week. London's cowsheds were almost emptied, and even in the rural areas many herds were swept away. My own grandfather started the winter with about 70 head of cattle, and was left, by springtime, with only one old cow. A neighbour fared even worse, losing another herd in the second epidemic of 1872.

Despite such setbacks, livestock improvement went on apace. Breed Societies, with their herdbooks, multiplied, and the export trade in pedigree stock, although fluctuating violently as boom and slump succeeded one another in the new countries, reached large dimensions and brought in big money. Progress indeed, was uneven ; the interest of the landowner and the well-to-do farmer, as well as that of the exporter, was largely in beef cattle, draft horses and sheep. The dairy cow and the pig were left in comparative obscurity.

The Years of Adversity Times had deteriorated in the later 'seventies, and the last year of the decade brought one of the worst seasons, and harvests, of all time. Moreover, the high prices that had formerly compensated the farmer in such years did not materialize. Cheap corn had come to stay, and a few more years were to see the arrival of the first cargoes of frozen meat from the other side of the world. Australian wool had already altered the prospects of the sheep farmer.

It had been the corn-and-meat producer, in particular, who flourished during the good times, and it was he who now bore the brunt of the depression. Half of Essex went bankrupt, and the land passed to "incomers"

who understood other ways of using it and who were prepared to accept a labourer's standard of living. There was nothing like that in Cheshire or Devon.

It was natural that many farmers should have turned to dairying, for the milk market was expanding fast. It was natural, too, that others should put away the plough and take to the dog and stick. Both were concerned with grass, and it was to be expected that the 'eighties and 'nineties would witness a growing interest in pasture-making and management.

Unfortunately, in 1879, nearly everything remained to be learnt. Leicestershire and other counties indeed had fields that would fat a bullock on every acre, but nobody could explain how they had come to be. Half a century earlier Yorkshire farmers had discovered that bone meal was a "famous manure for grass," and mass applications had doubled the output of cheese from many a Cheshire farm. But nobody could explain to the impoverished farmer how he could create a tolerable sward of grass upon a worn-out arable field, and this was the advice that was so urgently needed.

To take but one point, the 'eighties and 'nineties saw a long and heated argument about the value of perennial ryegrass. On the one hand, it could be pointed out that this plant was the main constituent of the richest old pastures ; but, on the other, could anybody say that the plant, as grown from commercial seed, survived, in any considerable amount, beyond a year or two ? The main reasons for this contradiction of evidence were, of course, two—firstly, that ryegrass is useful only under conditions of high fertility, and, secondly, that the native strain, as it existed in good old pastures, was a very different thing from the "artificial" type from which the seed of commerce was derived. In practice, the farmer either let his worn-out land "fall down" or else sowed a mixture of commercial ryegrass and red and Dutch clovers, often blended with the sweepings of his hay loft. In any case, the immediate result was poor, and the ultimate outcome depended upon manuring and management over the years.

The first important step of progress was the discovery, in the late 'nineties, that basic slag would do substantially what bone manures had done for an earlier generation of improvers. Moreover, it was cheap enough to pay a handsome profit even at the prevailing low prices for meat and cheese. This was the lesson of Tree Field, Cockle Park. The second was the demonstration, especially by Elliott of Clifton Park, that the "natural" grasses—cocksfoot, timothy, fescues and others—could play an important role in pasture-making. Thirdly, in the early years of this century was the discovery that the native wild white clover, unlike its commercial relative, was a truly perennial plant. And fourthly, was the combined use of slag with the Cockle Park or Craibstone seeds mixture, which latter contained not only the "natural" grasses and wild white, but also the more enduring varieties of red clover, as determined by many trials. The crowning achievement was the working out, by Stapledon and his colleagues at Aberystwyth, of the breeding methods which gave us the "pedigree indigenous" strains of both grasses and clovers. In all this Britain led the world.

Between 1871 and 1901 the acreage of wheat fell by more than half, and that of the main arable crops by more than 20 per cent ; moreover, the decline in tillage was by no means at an end. It did indeed seem to Sir Daniel Hall, when he made his *Pilgrimage* in 1910–12, that a measure of stability had been achieved—that a tolerable living was again being made out of corn and sheep on the light arable, as well as from milk and grass on the old wheat lands. But by the 'twenties it was clear that the farmer's

troubles were by no means at an end. Moreover, there was no salvation in further grassing down, for this would have meant the replacement, on the lighter soils, of good arable crops by poor grass. It was the introduction of the sugar beet crop that saved these light lands, in Norfolk and elsewhere, from complete dereliction, and it was the work of the Sugar Beet Corporation, and of the Norfolk Experimental Station, that enabled the technique of its cultivation to be quickly worked out.

It must not be supposed that progress in crop production stood still during the years of declining tillage. There were important developments in plant breeding—John Garton's oats, Rowland Biffen's wheats, and a succession of improved potato varieties like British Queen and Up-to-Date. There was notable progress in vegetable production—the result of improved transport and changing dietaries ; so that the fenland and siltland farmers of Norfolk and Lincolnshire ploughed out while others laid away. Fruit growing and the glasshouse industry expanded, and growers quickly applied the new knowledge and resources that came to hand.

In the years between the wars, numbers of farmers found the solution of their economic difficulties by building up livestock enterprises—poultry, pigs and milk—upon the abundant supplies of important feedingstuffs that were available at prices far below the cost at which their equivalents could be produced at home. In this development they were greatly helped by the new knowledge of animal nutrition—largely derived from German and American researches, but adapted and interpreted by Wood, Crowther, Mackintosh and by Boutflour and other of the County Organizers. The tendency, however, was to carry the idea too far, so that the economy of many a farm came to be based on the meal-bag rather than the soil.

Later, in the early 'thirties, came the first experiments in all-out mechanization. These were based upon the belief that any revival of arable farming must depend on a revolutionary reduction in labour costs. The early horseless farming was necessarily ill-balanced—corn, hay and fallow—and most farmers, partly because they wished to preserve something of the old balance and partly because they could not lay hands on the capital required for re-equipment, preferred to mechanize by stages.

Balanced rations and combine harvesters were only two among the many aids to survival that the scientist and the inventor produced. In 1889, when the new Board of Agriculture was set up, Rothamsted was our only research station and Woburn our only experimental farm ; the Royal Agricultural College at Cirencester, Edinburgh University and two privately-owned institutions provided all that there was in the way of technical education ; and there were still no Agricultural Organizers. But in the following year public money was provided for technical instruction, and one county after another instituted lecture courses and advisory services. Moreover, several groups of counties clubbed together to found agricultural colleges or to finance agricultural departments in existing universities, which departments carried on extra-mural work as well as central teaching.

The planning of the new developments, and the training of the new generation who were to see these through, fell to a very small group of men, notable among whom were Middleton, Somerville, Wood, Biffen, Hall and Gilchrist. Their opportunities were greatly expanded by the passing of The Development Fund Act in 1909, which, for the first time, recognized that the promotion of agricultural research was a proper function of the State. But it was after, rather than before, the first World War that

most of our modern research stations came into being. Today the names of many are household words throughout the farming world.

1939 and After Many pages could be filled in outlining the war-time organization of food production and in assessing the achievements of the farming industry in the years of trial. Many more could be devoted to a discussion of the philosophy underlying our post-war agricultural policy and its effectiveness in operation—the policy of assured markets, guaranteed prices, security of tenure for the efficient farmer and the provision of adequate research, educational and advisory services. Many more still could be filled with a bare list of recent technical developments—antibiotics, chemical weed-killers and insecticides, trace elements and vitamins, new machines, new methods of plant and animal improvement, of pasture-making and management, and so forth. But it is probably well to leave all this to the future historian. Meantime we may perhaps leave the bare figures to speak for themselves.

The changing pattern of British agriculture from the peak of 1871 to the nadir of 1939, and back to the new peak of 1950 is shown in the following statistics :

Great Britain
Acreages of Main Crops and Numbers of Livestock
(*thousands*)

	1871	1939	1950
Crops (*acres*)			
Wheat	3,572	1,763	2,476
Barley	2,386	1,010	1,774
Oats	2,716	2,135	2,760
Potatoes	628	589	1,056
Sugar beet	—	345	429
Turnips and swedes	2,164	688	588
Mangolds	361	215	276
Seeds hay	2,165	1,689	2,575
Meadow hay	3,490	4,786	2,891
Livestock (*head*)			
Cattle	5,338	8,119	9,630
Sheep	27,120	25,993	19,714
Pigs	2,500	3,767	2,463
Horses	1,254	987	494
Tractors	—	55	293

An overall measure of the expansion since the last pre-war years—the quantum of net agricultural output—is obtained by valuing the total product at fixed prices and deducting the value, also at fixed prices, of imported feedingstuffs, seeds and livestock. The figures, taking 1936–39 as a base, are :

1936–39	100	1946–47	116
1942–43	120	1947–48	122
1943–44	125	1948–49	134
1944–45	120	1949–50	139
1945–46	121		

We cannot perhaps say, as Lavergne said in 1851, that British farming is the best in the world. But we can confidently assert, as he did, that " it is in the way of realizing further progress".

FARMING TODAY IN ENGLAND AND WALES

W. B. MERCER, C.B.E., B.Sc.

In this short survey, Mr. Mercer, the Director of the N.A.A.S. West Midland Province, shows something of the diverse character of our farming. Interested readers will find a fuller account in *British Farming*, which will be published shortly by H.M. Stationery Office.

OF the factors shaping British farming, climate is the chief, for the climatic differences between east and west, between mountain and lowland, are really very great. Corn harvesting under the great arch of East Anglia's smiling skies is one thing, and the endless shifting of sodden stooks in a sullen September in the west is another. It is hardly worth inquiring why the Pennines and the Highlands are given over to sheep, since only sheep can live—and not always they—in the wintry blasts which sweep those regions. Topography is of less account, its effects mainly indirect ; in all historical times the plains have attracted population and thus the uplands have lagged far behind the lowlands in the development of roads, houses, trading facilities and that odd assortment of blessings and burdens which pass under the name of amenities. Our soil pattern is very intricate. Hardly anywhere in Britain are there considerable stretches of uniform land ; most geological formations (and we have specimens of them all) give variable soils ; while glacial drifts, sometimes of great depth, sometimes mere "skitterings," add to the complexity, so that rich soils and poor, deep and thin, wet and dry, tend to occur in every parish.

To a great extent our farming has been made for us by our ancestors. It is a cumulative business, each generation starting where its predecessor left off, using the roads and ditches, hedges and housing it inherits; and each generation tends to start with the assumption that father had good grounds for practising a particular system. " My father, he says to me, John, he says, you remember this . . ." Who has not heard (or uttered) that kind of prologue to reminiscence ? But, considering our history, is this a matter for surprise ? Our genes come down to us from ancestors who ploughed the same fields in the Dark Ages, giving to us their cast of thought ; our bickerings today on corn growing and cattle rearing probably repeat those that occurred around the camp fires of our tribal forebears. We are " such stuff as dreams are made on".

Yet tradition is not only local ; still less static. It has always been moulded by the voices of great men and groups of men, and Britain has been favoured of the gods in her leaders of agricultural thought. No process of reasoning can account for the appearance of Robert Bakewell ; he just arrived. Apparently a man of very ordinary yeoman stock, he divined, and to some extent defined, the principles of animal breeding and set alight a flame which literally spread to the ends of the earth. If anyone can be said to have founded agricultural science, that achievement must be credited to Lawes and Gilbert. Some of the universities had indeed brought agriculture into their curricula, but the teaching must have been very empirical until the shrewd landowner and the patient chemist of Rothamsted had worked out a coherent theory of soil nutrition and established experimental work on a sure foundation. Towards the end of their long reign a group of workers in the north of England, led successively by Somerville, Middleton and Douglas Gilchrist, started work of a similar but different

pattern at Cockle Park. It had in origin purely practical ends ; but from it sprang all modern knowledge of grassland management. Not without reason can Tree Field be described as historic ground.

The outstanding feature of our times has been the introduction of science into an ancient craft. In great measure this follows from the provision of funds for research and education under the Development Act of 1909. From that date some dozen State-financed research institutions have come into being and their research has provided foundations upon which most of our technical progress has been based. It should, however, be added that, parallel with this development, there has been a remarkable expansion of research by private firms interested in agricultural requisites or products.

Until recently the main function of the State was indirect (animal health was, however, an exception) but the economic blizzard of 1929–32 brought to Britain, as to many other countries, a change in political atmosphere. There followed permissive marketing acts, tariffs, import quotas, differential payments and subsidies, and finally the directive powers assumed during World War II. We emerge from the battle clouds with an industry governed by the Agriculture Act of 1947, with prices for major agricultural products guaranteed by the State and a moral obligation on a host of independent producers to fulfil agreed national plans. The nature of the bargain would have shocked Adam Smith, but even that master's economic laws are not immutable. Official calculations show that the volume of net output today stands at over 140, compared with 100 in pre-war years, and the latest available estimate from the Oxford University Institute for Research in Agricultural Economics puts output per man at 25 per cent above pre-war level. Farming has become a coveted industry, and vacant possession of a farm has become an asset rivalling in value that of the land.

Dairy Farming Dairy farming, now practised all over Britain save in the mountainous parts, forms the largest section of the industry, whether measured in terms of monetary or social value. Co-operative marketing has permitted of smooth and rapid expansion in the past two decades. Conditions of milk production have improved fast under the joint direction of research institutes and watchful departments of State ; the creation of a public appreciation of the laws of hygiene is a tale upon which all concerned can look back upon with some pride. Elimination of T.B. now proceeds apace, though the start was slower than in some countries.

The chief agent in the business—the cow—is a remarkably adaptable animal, capable of thriving for part of her life on a daily ration containing about 7 lb. of starch equivalent one-tenth of which is protein, yet able in full milk to turn to good account food of three times the energy value, containing five or six times the quantity of protein. She has but recently acquired this flexibility of purpose. Till but yesterday—in the evolutionists' time scale—she was bred chiefly for her physical strength and her beef qualities. The first true breed which arose was the Shorthorn, and it is some testimony to the advance which this must have represented over the mongrel stocks of the country that, between the middle of the seventeenth and the end of the nineteenth century, practically all the cows in England, and a very large number in Scotland, conformed more or less to Shorthorn type. In recent years, and particularly since the outbreak of World War II, it has been top-crossed freely with the British Friesian and Ayrshire. Simultaneously the latter breeds and Channel Island breeds have been expanded. Fully half our stocks today must be of dairy or near-dairy type, a fact for which we may be grateful at breakfast time, but regret when the joint arrives at lunch.

All dairy farms have in recent times been subjected to a common strain ; all have today to wrestle with the same basic problem, that of providing the large quantity of protein-rich fodder demanded by the high-yielding cow. In days gone by this need was met by imported concentrates. During the war the plough transformed the appearance of dairy farms, but did not wholly solve the fodder problem, since protein-rich crops do not thrive in Britain. The plough can provide the means to keep the cow, but not the means to produce the milk.

For this reason the dairy farmer begins to look at grass from a new angle. Hitherto it has been regarded as the easiest of all crops to manage but the least productive. A wealth of evidence comes from the research stations and the experimental farms to disprove such fatalism. Given only a reasonable rainfall, grass can be made to yield energy approaching, and protein far exceeding, that of a green crop. The dairy farmer becomes, therefore, the chief exponent of intensive grassland management, strip grazing, grass drying, silage-making and the manufacture of super hay.

Beef About half our beef at present comes from cows or heifers which have been discarded from dairy herds. The more attractive part of our home-grown ration is derived from steers and heifers raised specifically for the purpose. Many of them spend the whole of their lives on one farm, but by far the greater number are destined to see two or three farms in the course of their existence, for there is a large traffic in livestock and their movements are as complicated as those of trucks on a railway system. Rearing is, however, most extensively practised in upland regions and fattening in lowlands. The general course of movement is therefore from west to east and two streams may be distinguished.

Many upland farms breed their own calves. A pedigree sire is used, the breed varying in different districts : in the Pennine and Border country it is usually the Shorthorn ; in Scotland, either Shorthorn or Aberdeen-Angus ; on the Welsh border the Hereford, and so on. Calves are born at pasture and are suckled by their dams throughout the first six months ; they are commonly sold as " three-half-year olds," i.e., at about 18 months of age. They pass on to lowland farms where grass of higher quality is available, and here they may remain until fit for slaughter, or they may be sold again for finishing on roots and other produce on the tillage farms of the eastern counties. Usually, however, since they have been started well they do not get beyond the grass farms of the Midlands.

A second larger stream originates on dairy farms. Calves of dual-purpose breeds, pure or crossed with beef sires, are sold on to rearing farms, where they are multiple-suckled, the usual allowance being six or seven calves per cow. They grow rather more slowly than those reared on their own dams, but their progress is not unlike that of the favoured few.

In both types of beef production growth tends to be concentrated in the summer months, while winters are lean periods of mere maintenance. This is obviously an economical procedure since grass collected by themselves is the cheapest cattle food. The system has, however, two defects, in that the cattle are slower in reaching slaughter weight than they would be if pushed along by liberal winter rations, and supplies of fat cattle tend to be seasonal. Prices apart, the main factor governing supplies of beef cattle is the quality of upland grazings. Great improvements have indeed been effected during the past ten years in the quality of upland grazings. Increases of productivity of the order of 400–500 per cent have been no uncommon experience. Large areas susceptible of treatment remain to be dealt with.

Sheep Sheep farming today is but a shadow of its former self; in mediaeval times England must have teemed with sheep. We have more than twenty distinct breeds. Types overlap so much that it is scarcely possible to devise a satisfactory system of classification. From a commercial and managerial standpoint, however, they fall broadly into two groups of hill and lowland type respectively. The broad objective of hill sheep farming is the development of hardiness and milking quality, while in the lowlands early maturity, i.e., the capacity to develop a carcass fit for the butcher at an early age, is the main objective. Most of the sheep in the country are cross-bred : the fount and source of them all is our mountain land. Nearly one-third of the land in Great Britain consists of hill grazing.

Wind, rain and snow make life on the hills extremely severe. Only the hardiest of breeds can endure the winter, and even they are subject to losses which would break any other type of stock-farmer ; some of our breeds, classified rightly enough as hill sheep, have to be wintered off the hills. Grazings fall broadly into two types—heather and grass respectively. Of the heather-feeding type, the Blackface is by far the most numerous breed. Of the grass types, Cheviots are perhaps the most widely spread, though Wales is stocked mainly with its native hill breed.

An extremely complicated system of cross breeding is in existence. Hill breeds are systematically crossed with larger types, of which the Border-Leicester is perhaps the most famous, to give hybrids which form the staple stock of much of the uplands. In the uplands, and again on lowland farms to which a great many upland stock are ultimately transferred, these hybrids are mated to Down sires and the second cross, or quadroon, may be mated in the next generation again to a Down type. Thus a gradual watering down of the original hardiness of the hill blood is effected but simultaneously early maturity is injected. Amongst the achievements of our times has been the control which veterinary research has given the flockmaster over some of the major diseases which infected sheep. The present outstanding problems are those of hill grazings and herding—the one technical, the other social. Costs of land improvement rise steeply as the land itself rises in altitude. As the urge for community life develops, the attractiveness of the " homely slighted shepherd's trade," with its inevitable loneliness, declines. Nevertheless sheep stocks are rising ; they stand today at over 20 million and provide us with about one-sixth of our total home-grown meat.

Arable Farming All farms in Britain are today more or less arable, but the bulk of our tillage land is to be found in the eastern half of the country. Whereas the western farmer looks to his arable land primarily as a source of fodder for his stock, men of the eastern counties grow crops primarily for direct sale and stock are in general a secondary matter. Largely in consequence of this difference in objectives, the east has been subject in the past to much greater fluctuations in prosperity than the west, and the beet industry was created by deliberate act of the State to introduce an element of stability. The crop provided at once a reliable source of revenue, and it was foreseen that it would help to maintain soil fertility and keep alive the arts of cultivation.

Systems of land management have evolved from the simple four-course known as the Norfolk rotation. Over large areas corn growing has been extended by the introduction of additional wheat or barley crops. This extension has encouraged the development of mechanical methods of harvesting, and the combine harvester now tends everywhere to replace the binder. There is little evidence of any decline in fertility arising from

excessive growing of cereals, though these crops are admittedly extractive. Weed risks have to a great extent been overcome by the power and speed which tractors have brought. Certain weeds, however, remain almost immune from attack by cultivation only, and here modern herbicides are proving of great value. During the past few years there has been some movement towards leys of longer duration than the one-year which has hitherto characterized rotations, and lucerne growing develops steadily. On the debit side must be set considerable ravages of certain fungoid diseases of straw—Take-all and Eyespot are the chief—which clearly arise from overcropping. Fortunately both diseases are largely seasonal and to some extent they are correlated with soil type.

In certain districts of specially favourable soil, notably in the fens and the silt lands adjoining them, farming has evolved in a different direction. Here potatoes and vegetable crops are specially attractive owing to the soil conditions and the immense crops which can be grown. In such areas rotations tend towards simple three-course shifts—potatoes—sugar beet or vegetables—wheat. Some variety is introduced by such special crops as peas, carrots, mustard and linseed. The potato is, however, the key crop of all these areas. Storage of the harvested crop in barns built for the purpose is a notable development in recent years. The most serious trouble arising from this intensive system of cropping is the potato root eelworm. This constitutes a problem in plant protection which challenges scientists and farmers alike.

Pigs and Poultry Both pigs and poultry are fed almost exclusively on grain. Before the war about one-half of our wheat crop and one-quarter of our barley were fed to livestock, mainly poultry and pigs, but even so the bulk of our bacon and eggs were produced from imported foodstuffs. In the Large White we probably possess the best basic material for bacon production in the world ; certainly it has been used very widely in the foundation of bacon strains. It crosses well with other breeds, and much of our own commercial breeding today consists either in straight Large White production or in matings of this breed with types such as the Essex, Wessex or Large Black. As in beef production, there tends to be a division of the industry into two sections, the one devoted to rearing, the other to fattening, but specialization has not been carried very far and the bulk of our supplies probably come from farms on which pig-keeping is a side-line. There is, however, a notable concentration in East Anglia where plentiful supplies of potatoes and tail corn of low quality provide the basis of feeding.

Poultry-keeping has evolved as a distinct enterprise during the present century. Specialists within the specialist craft soon arose ; some men, adopting closely controlled systems of management, emerged as breeders supplying stock to others who became egg producers. Later, incubation split off as a separate section, and hatcheries buying eggs and selling chicks developed. Now most of our stock are bred by specialists registered by the State as accredited breeders, and sold as day-old chicks or young stock on to general farms, where they are managed by the women-folk. Several distinct systems of management can be recognized : colony houses fixed on pastures or sometimes on leys and holding 50–100 birds are still perhaps the commonest type. On other farms batteries of small movable houses with runs attached are employed. There is, however, a marked trend towards maintenance of birds close to the homestead—in batteries of small cages, in houses from which litter is seldom removed, or in yards where birds are treated much in the same way as fattening cattle.

Market Gardening, Hops and Fruit Though the main strongholds of market gardening are still the environs of towns, vegetables and fruit are now grown wherever soil and climate are suitable. Vegetable crops are a feature of farming in Bedfordshire, the Vale of Evesham, the Wisbech district of Cambridgeshire, around Botley in Hampshire, Swanley in Kent, Ormskirk in Lancashire, the Tamar Valley and so on. No business of our day is more subject to that curious combintion of shrewdness and whim called consumers' choice. The industry is subject, too, to great fluctuations of fortune with seasons. It is for this reason primarily that most market gardeners grow so many different things. They provide in their variety a form of insurance.

Two divergent trends may be noted, the one towards generalization, the other towards specialization. The vegetable crop has become a farm cash crop : a farm crop differing from the green crop only in the fact that it is sold off instead of consumed on the place. On the other hand, a highly specialized craft of glasshouse cultivation has grown up, the most notable area being on the northern outskirts of London : the Lea Valley concentration of tomato and cucumber houses is probably unique.

Hop growing is carried on in two centres only, the one in Kent/Sussex, the other in two river valleys of Hereford and Worcester. The crop is confined to soils of exceptional depth and fertility.

Fruit growing is, however, by far the largest specialized section. Mainly an affair of the south country, this branch of farming is a development of the past half century. In that period, thanks to the work of research stations, and in particular to East Malling, scientific method has steadily displaced empiricism. Growers have had " a pearl of great price " in the incomparable Cox, and upon it their early fortunes mainly hung. But, as with other types of high-grade production—designated milks, certain vegetables, pedigree poultry—progress has turned on the spirit of the pioneers, not all of whom were men of the fields. For the ascent has been no easy one, free of checks and hindrances. Rather has it been toil upwards through the night.

A types of farming map is shown opposite p. 51.

A HUNDRED YEARS OF SOIL RESEARCH

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Traditional farming practices may often be found to be sound, but their intelligent application and their full implication must depend ultimately upon knowing the " reason why ". In no sphere is this truer than in soil science, as Dr. Russell shows in the following brief survey.

A HUNDRED years ago soil science barely existed. Instead there was a great body of practical knowledge of the soil handed down by tradition, and although the practices were often sound, the reasons traditionally given for them were often wrong. Hence much of soil research has been devoted to finding out the correct reasons for traditional practice.

The great names in soil science a hundred years ago, or agricultural chemistry as it was then called, were Liebig in Germany, Boussingault in France, and Lawes and Gilbert in England, and they were all interested in finding ways of increasing crop yields by adding suitable plant foods to the soil. Boussingault and Lawes differed from Liebig in that they each had a farm on which they could make their experiments and demonstrate their

results to farmers. So successful were the Rothamsted experiments in showing how yields could be increased that the Station soon acquired a world-wide reputation, which has been maintained by the three Directors who followed Gilbert—A. D. Hall, E. J. Russell and W. G. Ogg. But Hall and Russell also carried on Lawes and Gilbert's outlook of regarding the soil as a medium for crop growth, and since Rothamsted was the only soil research station in Great Britain for much of this period, this aspect reigned supreme in Britain until recently.

Another outlook on soil research was however being developed on the Continent at the beginning of this era, in which the properties of the soil were studied without reference to the fact that the principal use of the soil was to support crops. The original aim of this work was to describe as accurately as possible the properties of the soil as it exists in the field (often however for purposes of land taxation) and then to find out why each soil had its own particular characteristics. This branch of soil science has been called pedology, and it was introduced into this country only about twenty-five years ago by G. W. Robinson of Bangor and W. G. Ogg of Aberdeen. Neither of these two workers had at that time a large laboratory, so that these pedological studies have developed rather slowly, and it was only with the establishment first of the Macaulay Institute in Aberdeen and then of the Pedological Department at Rothamsted, both under the direction of Ogg, that any appreciable numbers of workers were engaged to pursue these studies.

The Biotic Conditions in a Soil Crops can flourish in a soil only if their roots can ramify freely, and they can do this only if the soil is not too acid and if there is an adequate supply of oxygen to their roots and not too high a concentration of carbon dioxide. Further, it is essential that the roots can extract adequate amounts of water and nutrients from the soil. The soil scientists' achievements during the last hundred years in the study of these conditions, have been the clarification and making exact of ideas which previously were only vaguely guessed.

It had long been known that liming a soil may improve its fertility, but it was not until 1891 that first Wheeler at Rhode Island and then J. A. Voelcker at Woburn, an experimental farm financed by the Royal Agricultural Society, showed that soils could be acid, and that this acidity will cause crop failures and stunted root systems. But only recently have all the soil factors causing this failure been appreciated, for it is not primarily the soil acidity itself which is harmful, but the high level of available aluminium and manganese in the soil and the low level of available calcium which accompany the acidity. For many practical purposes it does not matter which of these factors is responsible in any particular soil, because liming neutralizes them all ; but as Wallace and his co-workers at Long Ashton have shown, it is of great importance that the reasons for the tolerance of some plants to acid soils, and probably also their ability to take up phosphates from them, should be understood.

The importance of an adequate air supply to plant roots is now well appreciated ; there is no easier way of killing the rootlets which are active in the absorption of water and nutrients than by allowing the carbon dioxide concentration around them to build up to too high a level. Both healthy roots and the soil organisms are continually using up the oxygen in the soil air and respiring carbon dioxide into it ; and this carbon dioxide diffuses into the atmosphere, and atmospheric oxygen diffuses into the soil through the air spaces there. Only if there is a well-distributed system of air pores in the soil, running from the actual surface of the soil down to the bottom of the root zone, can the soil be well aerated. Sealing the surface pores of

the soil, as may happen if it caps badly after a heavy storm, may allow the carbon dioxide concentration in the soil to increase over ten-fold in two warm summer days—a rise that may kill so many of the delicate absorbing rootlets that the plant will suffer severely from lack of water. Only by hoeing the soil surface as soon as possible after the storm and whilst it is still wet, can this damage be avoided.

The importance of the soil tilth now appears to lie largely in its effect on the aeration of the soil, for only soils whose surface is made up of fairly small crumbs can contain the intricate system of coarse air pores needed for good aeration. It is obviously of great importance that these pores should remain open all the time the crop is in the ground, in spite of storms, cultivation, and other disturbing factors. Sandy, silty and some clay soils can possess this well-developed crumb structure only if there is an adequate amount of organic matter in the soil. And this can be in the form either of humus (i.e., well-decomposed organic matter) or of the roots of certain grasses, and probably also lucerne. Grass roots are more effective than humus, but their effect will rarely last for more than two or three years after a long ley or old pasture has been ploughed out. Hence it is on soils not naturally possessing a good, strong crumb structure that alternate husbandry can be so valuable and the regular dressings of farmyard manure or compost so important.

The reason that a well-drained soil can hold water against drainage and the conditions under which water can move through a soil have been clearly described only during the last fifteen years, largely due to the work of Schofield and Penman at Rothamsted and Nicholson and Childs at Cambridge. The principal factor limiting the rate of movement of water in moist soils is its viscosity, for though viscous liquids can move quite easily in wide pores or films, their rate of flow becomes immeasurably slow once the thickness of the film, or the size of the pore through which the liquid is moving, becomes too fine. Thus it is the control that viscosity exerts on the rate of movement of water in the soil pores that determines the amount of water a well-drained soil can hold against gravity and that can be lost by evaporation from an initially moist bare soil. A corollary to this is that rainwater can drain through the soil only if there is a large number of coarse pores in the soil reaching from the surface of the soil down into the subsoil or the drains ; and this is exactly the necessary condition for a moist soil to be well aerated, and it is assured if the soil has a suitable crumb structure, that is, a good tilth.

Soil Cultivation Ideas on soil aeration, soil water and soil tilth have recently been combined with theories of why soil cultivation is necessary. Until about thirty years ago hardly anybody seriously questioned the explanations that had been current to justify traditional practice, and when doubts were cast on these explanations and teachings, all of which had originated in Western Europe, it was from farmers of European stock who were practising these methods under widely differing conditions that they came. Two groups of problems have received a great deal of attention: (1) the effect of hoeing between the rows of a widely-spaced crop during a drought on the amount of water available to it, and (2) the need for the mouldboard plough.

Hoeing is still considered by some farmers to save water, yet in well over a hundred experiments made between 1880 and 1910, in various parts of the United States, most of which had dry summers, hoeing was found to confer no benefit, except to kill weeds. The mouldboard plough was considered essential for breaking up the land for a seedbed, yet because it leaves a bare

soil surface, it has been the cause of very serious soil erosion in many parts of the world, particularly when used, as so often in England, to plough straight furrows up and down a slope. Much work done in the tropics, in the semi-arid areas of the world, and in Western Europe, including Great Britain, has shown that one of the most important functions of cultivation is to control weeds, and that provided the weeds are controlled, the actual method of loosening the soil chosen depends on such conditions as the liability of the soil to erosion, loss of water by evaporation, and similar factors. The advantage of the mouldboard plough in Western Europe, where soil erosion is not a serious problem, is that by burying all the weeds under the furrow they are either killed or very seriously weakened, even in wet weather. It is being replaced, wherever the climate is fairly dry, by methods of undercutting all the weeds, but leaving them to die on the soil surface, and at the same time leaving all available organic matter such as straw, stubble, or grass mulches lying on or anchored in the surface of the soil.

The first function of soil cultivation is to kill weeds, the second to ensure that, even when the soil is wet, there is a well-distributed system of pores containing air permeating the soil from the surface downwards. Cultivations by themselves can often ensure this, but sometimes they can only do so when used in conjunction with a proper system of cropping, manures, or mulches.

The justification for using depths of cultivation greater than a few inches on well-structured soils is still undecided, provided these shallow depths give an efficient control of weeds—which they rarely do in this country. However, if the soil does not possess a natural system of coarse pores in the subsoil, either because it has been damaged by bad cultivation or because the subsoil is compact and structureless, then deep tillage may be of value since it can produce a system of wide pores. These deep tillages will have to be repeated regularly if soil particles flake off from the surface of the soil clods and fill up the pores made by the cultivation implement, as happens in some fine sand and silty soils.

The Value of Farmyard Manure One of Lawes's original problems at Rothamsted was to discover why farmyard manure increased soil fertility so markedly, for he knew he could not make enough manure from the products of the farm for maximum crop yields. His first experiments with wheat on Broadbalk gave the principal reason immediately : it supplied certain inorganic foods needed by the plant and, in particular, ammoniacal nitrogen, and these could equally well be added as chemicals, or artificial fertilizers as they were called. This result was so revolutionary that it has been a stumbling block to many farmers ever since ; in point of fact it is not true for some sand silts or heavy clays, though it probably is for most soils ranging from light to heavy loams. Hence from Lawes's time to the present day, studies on farmyard manure have been a prominent feature in the Rothamsted research programmes.

Lawes and Gilbert realized that if the value of farmyard manure mainly lay in the content of inorganic plant nutrients, then its value depended both on the kind of food consumed by the animal and on the kind of animal making the manure. Thus they showed, first approximately in 1854 and then more exactly in 1862, that all the plant nutrients present in the food consumed by the animal, and in particular the nitrogen, was either voided in the urine and faeces or retained by the animal for body building or milk production. Hence the richer in plant nutrients the food consumed by the animal, the greater was the manurial value of the dung produced : a result which has unfortunately been amply verified by farmers since 1940 after

concentrated feedingstuffs became scarce ; for the manurial value of much of the present-day farmyard manure is definitely lower than that made before the war.

Lawes and Gilbert also showed that whilst nearly all the potash and phosphate voided by the animal should reach the field if the manure was well made, this is not true for the ammoniacal nitrogen, for there was always a large loss of ammonia however well the manure was made. On the basis of this work Lawes and Gilbert drew up a set of tables for the compensation due to an outgoing tenant for the unexpired manurial value of the feedingstuffs that had been consumed on the farm during the previous three years; and these tables are, in the main, still used today.

Warington, another famous Rothamsted worker in the 1880s and one of the founders of the science of soil bacteriology, investigated the cause of the nitrogen loss found by Lawes and Gilbert, and showed that besides the loss of ammonia due to its volatilization, which gives the manure heap its characteristic smell, there was a further loss that had not previously been recognized. Whenever ammonia was present in a well-aerated soil or manure heap, it was liable to be oxidized by bacteria to nitrates, and whenever nitrates were present in a poorly aerated soil or manure heap, they were reduced to nitrogen gas. These two processes—nitrification and dentrification as they are called—occur in the outer layers of a manure heap and in soils well supplied with organic matter which become poorly aerated when wet. They are still recognized as being the principal, and perhaps the only, method by which nitrogen compounds available to the plant are converted into gaseous nitrogen, and so lost from the soil or manure heap ; and this loss is important not only in manure heaps but when old pastures are ploughed out or large dressings of farmyard manure are repeatedly applied to a soil.

This interest in farmyard manure was extended by Richards and Hutchinson in the early 1920s to the study of what happens when straw and animal droppings rot down together to form farmyard manure. They showed that straw could rot down quickly only if the micro-organisms carrying out the decomposition found all the nutrients they needed for rapid multiplication, but that they could not rot down moist straw quickly because there were not enough nitrogen compounds present in the straw for their rapid growth. Hence the reason straw could rot down quickly in a manure heap was that the dung and urine voided by the animals supplied the micro-organisms with the extra nitrogen required. This nitrogen could, however, be equally well supplied by organic nitrogen manures such as dried blood, or by inorganic fertilizers such as cyanamide or sulphate of ammonia, although in the latter case some limestone must be added to neutralize the sulphuric acid set free. These composts made without the aid of the animal appear to be as valuable for improving the condition of the soil as a farmyard manure, and they are fairly widely used by many market gardeners.

Soil Organisms and Micro-organisms A hundred years ago it was unlikely that anybody realized that the soil was full of micro-organisms, and it was not until the early 1880s, when medical bacteriologists were developing suitable technique for the study of human diseases, that any systematic study of soil micro-organisms was made. These early workers looked for and found bacteria, and for the next forty years the principal micro-organisms studied in the soil were the bacteria. It was soon realized that most of the soil bacteria had nothing to do with disease, but that they were responsible for such valuable processes as the decomposition of plant remains to produce humus, ammonia and nitrates,

and that they could fix atmospheric nitrogen under certain conditions. Hence came the theory that the bacteria were the primary cause of soil fertility, so the higher the bacterial population, or at least their activity, the more fertile the soil. And this was thought to be confirmed by Ashby's discovery at Rothamsted in 1904, and Russell's at Wye in 1905, that both the rate at which nitrification can proceed in a soil, and the rate at which soil can use up oxygen to produce carbon dioxide, increase with the fertility of the soil as measured by crop yield. These results are now known not to be generally true, but it was on this theory that Russell explained his discovery of the great increase of fertility brought about by partially sterilizing a soil, either by heat or with antiseptics, for he showed that this process also increased the bacterial numbers in the soil. He argued that the fertility of the unsterilized soil was lower than that of the sterilized because something was feeding on the bacteria, so limiting their numbers, in the unsterilized soil that was not present in the sterilized, and this something he showed were microscopic animals called protozoa. It is now known that this theory is wrong ; that in fact bacteria may work even more actively and efficiently if they are being grazed by protozoa, but it stimulated work on these other groups of soil micro-organisms.

More extensive work has shown that there is no direct connection between bacterial or microbial numbers and soil fertility, although soils that are very acid, very low in plant nutrients or poorly aerated usually carry poor crops and few micro-organisms. The primary function of the soil micro-organisms is, in fact, to decompose organic matter, e.g., plant roots, dead leaves or manure added to the soil, and the more organic matter that is added the more active, and probably also the larger, is the population of micro-organisms present. Hence although adding large amounts of organic matter to a soil is one way of maintaining soil fertility, the use of fertilizers, which in general do not affect the activity of the micro-organisms, is another and often more effective one.

There are also present in the soil a host of animals besides the micro-organisms, and of these the earthworms are probably the most important in many agricultural soils. In 1881 Darwin published his great study of what earthworms do in the soil, and subsequent work added little to his findings for many years. It was not until the zoologists had correctly identified and named the different species of earthworms present in the soil that further progress could be made. In the last ten years Evans at Rothamsted has shown that one should not talk about what the earthworm does in the soil because the different species do different things ; only a few make worm-casts on the soil surface, only a few channel into the subsoil, only some loosen the surface soil, only some flourish in arable soils. Different species probably also feed on different foods and differ in their effects on the soil humus and soil structure. At the present time these different effects of worms are receiving considerable attention, so that before long it should be possible to describe the condition under which each species flourish, and so be able to alter the soil conditions to encourage whatever species are likely to be the most helpful. Thus it is possible that one of the reasons for the value of gang mowing of grass orchards is that it encourages either certain of the deeper-burrowing or of the surface-burrowing species.

Soil Humus Researches into the nature of humus have been going on for the whole of the last hundred years, but we still cannot say exactly what humus is. A fundamental difficulty has been that there is no known way of separating humus from the mineral matter in the soil without

radically altering its composition ; and many of the earlier results are of limited value, as they concern the properties of some of these altered substances. Two methods of approach are possible. One is to find out and measure those characteristic properties of a soil due to the presence of the organic matter it contains, and the other is to devise new methods of separating various components of the humus from the soil without altering them chemically. Recently, advances have been made along both these lines, and much of the work has been done at the Macaulay Institute at Aberdeen and Rothamsted.

There is as yet no agreed theory on the constitution of humus. It is undoubtedly a mixture of different compounds, some of which appear to be derived from the bodies of the micro-organisms decomposing the organic matter added to the soil and some from the plant lignins, and it is these latter compounds that are mainly responsible for the dark brown to black colours characteristic of most types of humus. Some of these compounds may be built out of definite molecules without themselves having a definite structure, in the same kind of way as some present-day plastics ; and if this is correct it would explain why only breakdown products of these humic substances, and not the substances themselves can be separated from the mineral soil particles.

It is not surprising that we know so little about how humus is produced when our knowledge of its constitution is so limited. Micro-organisms, and possibly some of the larger soil animals such as various species of earthworms, are the primary agents causing the formation of humus. Soil conditions, such as the degree of aeration, and the lime or calcium status, also affect the type of humus formed. Thus well-drained neutral soils tend to have a black humus and poorly drained acid soils a brown humus. But nothing is known about the relation between these conditions and the humus-forming organisms or processes in the soil.

The various constituents of the humus have differing properties, but their relative contribution to the net effect of humus on soil tilth or the availability of trace elements such as manganese and copper to the plant have not yet been worked out. There is some evidence, however, that the dark-coloured substances derived either from plant lignins or microbial lignin-like compounds play a very important role in improving the tilth of a soil, and that the blacker the product the greater the improvement a given amount can bring about.

Conclusions The main conclusion drawn from this review is that the major soil factors controlling growth now seem to be recognized, and there is a considerable body of exact knowledge about their relative importance and how far they can be controlled. This review has not, however, discussed many important problems which are still awaiting solution in spite of much intensive work, such as, for example, the chemistry of what happens when superphosphate is added to a soil, or the availability to crops of the various phosphatic and trace element compounds in the soil.

The period under review started from the position that the main problems of soil science were concerned with altering the soil conditions so that crop yields could be increased. Whilst this is still the ultimate justification for much of soil research, the period has ended with the realization that many problems in soil science, in particular those concerned with soil microbiology and humus formation, and with the chemical processes by which rock particles weather into soil, must be studied without any direct reference to the fact that the primary function of the soil is to support crops.

The Pattern of the Fields

FROM any coign of vantage the pattern of our fields spreads itself in a unique beauty—like a lovely, many-hued garment thrown down in sweet disorder. Small, irregularly shaped fields, infinite in their variety yet each a plot of promise and reward, are bounded by hedgerows and intersected by twisting narrow lanes. Here and there the glint of a stream that flows irresolutely to the more purposeful river, a farmstead nestled under the shoulder of a hill, a patch of woodland and, beyond, a few cottages cast like dice upon the margin of a village which clusters about its ancient church. Below, ribbon-like, the " rolling English road " leads to the market town, self-conscious in its age-old importance.

This is the fabric of our farming, spun in tradition and woven by man and nature in understanding. Geography, history and economics have played their parts in the designing of the pattern we see today, but over all there prevail the immutable laws of good husbandry, whether of crops or stock, honoured by countless generations of landowners, farmers and their workers.

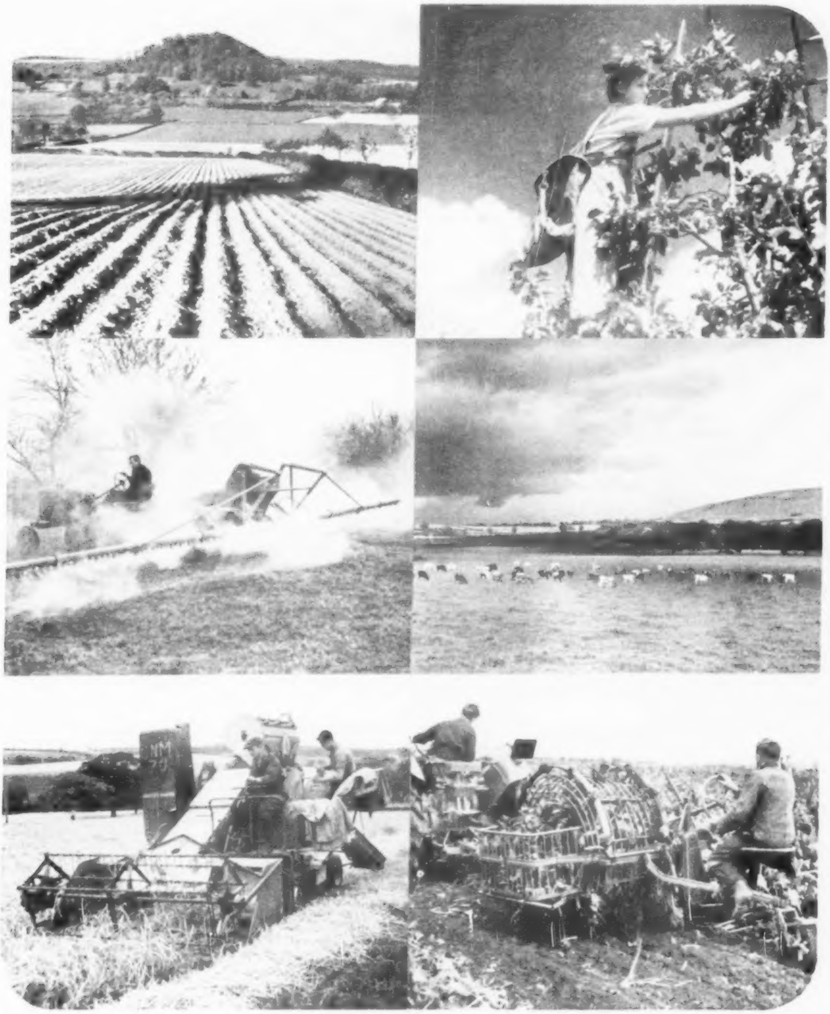
Of the 58,340 sq. miles which comprise England and Wales, over 80 per cent is, after nearly two hundred years of industrialization, still in agricultural production by some 250,000 farmers, most of whom are farming on a small scale, but under widely differing conditions of climate and soil. There are marked differences in climate between the drier east and the wetter west, the cooler north and the warmer south ; the soils, highly diversified, range from heavy clays, marsh and alluvial silts to thin-soiled uplands and mountain slopes. And naturally these factors are reflected in the types of farming which have evolved : arable and mixed arable and stock farms, as in the Eastern counties, where wheat, sugar beet, potatoes and other cash crops are grown, along with dairying and the fattening of cattle, sheep, lambs and pigs ; the beet and barley farms on the light soils of Norfolk, the chalk wolds of East Yorkshire and the sands of Sherwood Forest in Nottinghamshire ; market gardening and fruit growing on the rich soils of the Vale of Evesham, around Wisbech and in parts of Kent ; the extensive glasshouse area in the Lea Valley. Heavier concentrations of mixed farms are found in the middle belt : along the north-west coast, in parts of the Chilterns and West Sussex, where the emphasis is on dairy herds, and considerable areas of both fodder and cash crops are grown : over to the west, in parts of Herefordshire, for example, stock rearing is supplemented by fruit, hops and barley ; on the larger (chalk) farms of Wiltshire, Hampshire, Berkshire and Dorset, corn, dairying and sheep. The fattening of cattle, sheep and lambs is traditional to the famous pastures of Leicestershire and Northamptonshire ; in the hill districts of the lower Pennines, the Lake District and Wales, interest is centred primarily in the rearing and grazing of sheep and cattle, and some dairying. Small dairy farms and market gardens around the fringe of towns, and the production of early vegetables and cut flowers in the warm south-west corner of Cornwall are of economic significance. But for all this diversity, there is a close inter-relationship integrating the whole.

Something of the pattern of our fields is shown in the following art supplement ; in the space at our disposal it cannot be representative—only typical.

To these fields new ideas, new methods and new machines are constantly being brought. Time cannot be stayed ; the old generation hands over to the new, not only a farm here and a holding there, but a legacy of trust.

S.R.O'H.

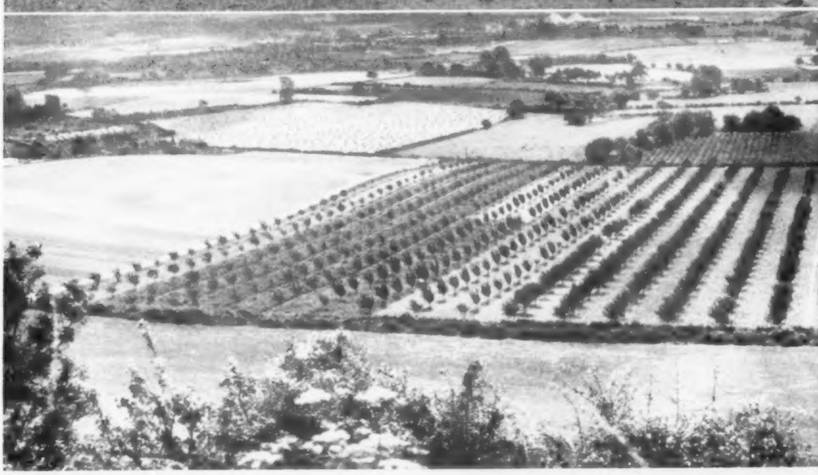
The Pattern of the Fields



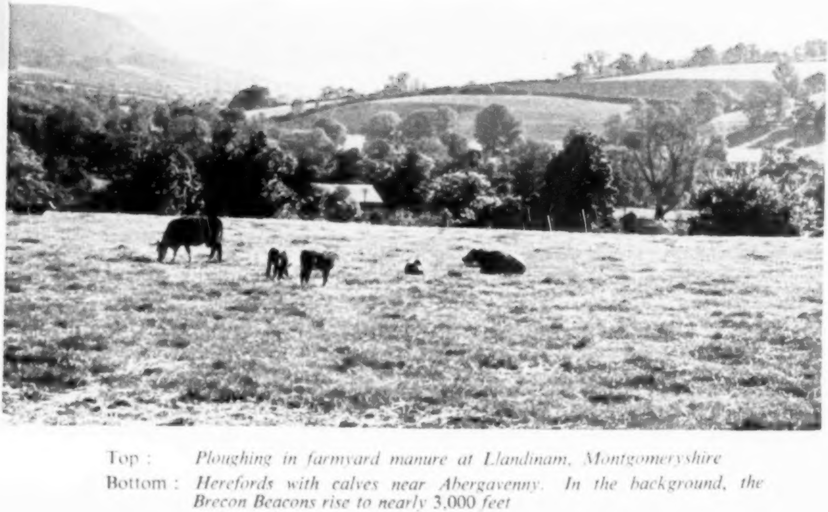
Lord, 'tis Thy plenty-dropping hand,
That soiles my land ;
And giv'st me, for my Bushell sown,
Twice ten for one.

Herrick

Top : *A Chiltern farmstead*
Centre : *Blackface sheep on a Yorkshire Dales farm*
Bottom : *Hampshire sheep near Andoversford, Gloucestershire*



Top : *Romney Marsh sheep in their native setting—a flat expanse of 92 sq. miles*
Centre : *Kent ("The Garden of England") seen from Wrotham Hill*
Bottom : *Part of the thousand acres of glasshouses which stretch up the Lea Valley to the north-east of London*



Top : *Ploughing in farmyard manure at Llandinam, Montgomeryshire*

Bottom : *Herefords with calves near Abergavenny. In the background, the Brecon Beacons rise to nearly 3,000 feet*

Top : *Harrowing on a hill farm near Towyn, Merionethshire*
Bottom : *Welsh Black cattle on the border of Brecon and Radnor*

Single-furrow tractor, mounted reversible plough at work in Essex

Walking type rotary hoe turning-in orchard weeds

Six-row drill on self-propelled tool chassis working in a confined space

Cultivating potatoes with tractor-mounted spring-tine cultivator in the Fens

One-man farmyard manure loader and spreader at work in Bedfordshire

Two-row tractor-mounted semi-automatic potato planter with fertilizer attachment

Tractor-mounted buckrake collecting silage crop in Gloucestershire

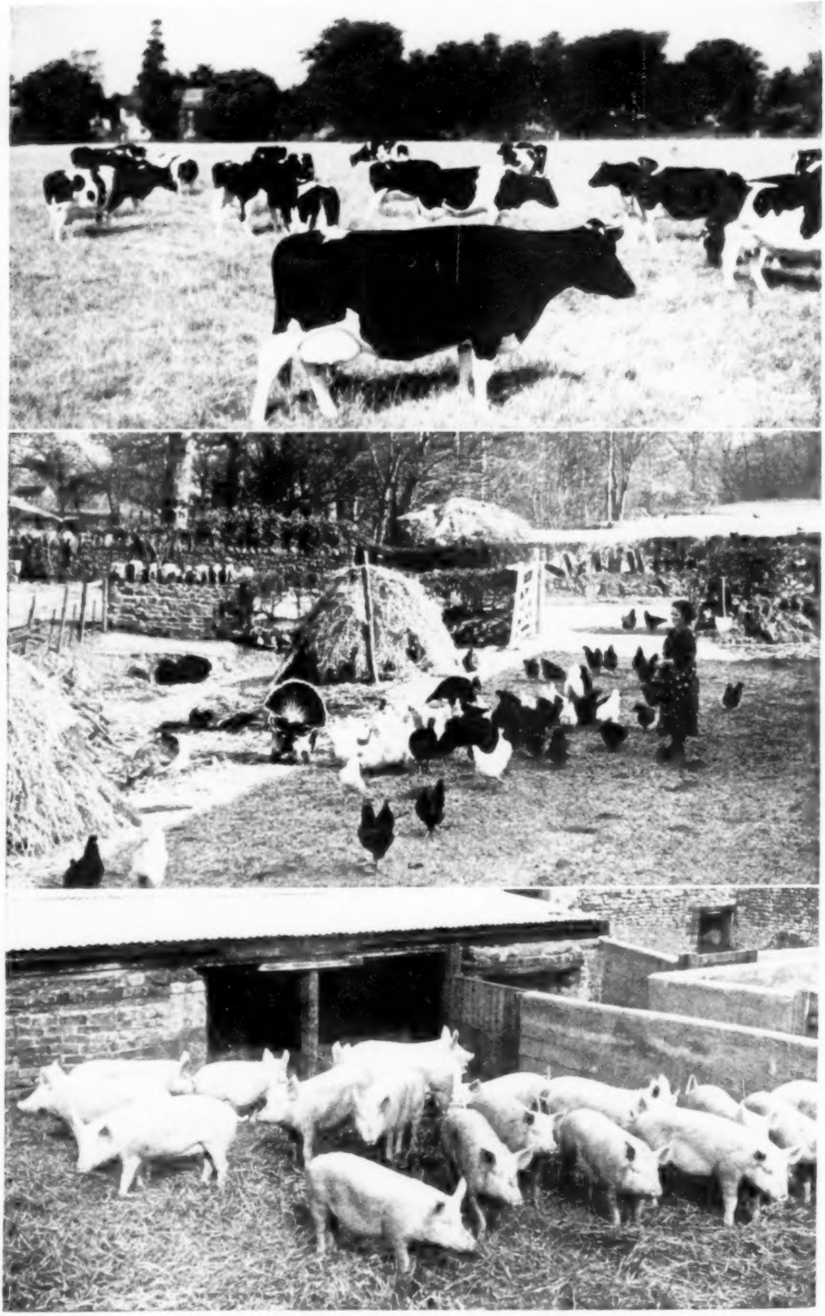
One-man green-crop loader with self-emptying trailer

Complete potato harvester at work in the Isle of Ely

Complete sugar beet harvester windrowing on a Sussex farm

Self-propelled 8 ft. 6 in. cut combine harvester in a crop of barley in Bedfordshire

Tractor-mounted hedge trimmer dealing with a neglected hedge in the Home Counties



Top : Pedigree British Friesians in Essex
Centre : Family farm in Cumberland
Bottom : A useful batch of Large White stores on a Yorks E.R. farm

REVOLUTION IN GRASS

SIR R. GEORGE STAPLEDON, C.B.E., F.R.S.

The importance of grass as a crop in its own right and one having vast undreamed of potentialities for greater food production, is now becoming increasingly recognized. More than to any one other person, we are indebted to Sir George Stapledon for his unremitting prosecution of the modern revolution in grass, which he briefly describes in this article.

IN its quiet and peaceful way the revolution in grass which has taken place during the last fifty years will almost certainly prove to have been as far-reaching as many another, and far more noisy, revolution in thought and action of which we of this century have been the agitated participators and witnesses.

To realize fully the implications of a revolution, it is necessary to have been at close quarters with it during its early beginnings, its ebbs and flows and when in full spate. I have been such a witness of the grass revolution in this country. When reading agriculture at Cambridge I spent the long vacation of 1908 at Halsdon Barton, Holsworthy, Devon, the farm of the late Abraham Trible, a leading breeder of Red Devons. He was a keen improver ("improver" was the correct word then) of permanent grass and rough grazings. How well I remember being vastly intrigued by his enthusiasm for the teaching of Somerville—a man he had often met and who to me at that time was only a revered name. Trible had gallantly carried slag not only on to his tolerably good permanent pastures (which in those unregenerate days were sacrosanct) but also on to some semi-boggy rough grazings—no mean pioneer effort in 1908 !

Slag certainly did its work in a seemingly miraculous manner. That "rough," instead of being a wiry spindly herbage with a woody birdsfoot trefoil the only legume, was a mass of white clover, with nice leafy *agrostes*, plenty of crested dogstail and a sprinkling of ryegrass—but it was the stock's appreciation of the " new look " that set Trible agog.

Foreshadowings There cannot be the least doubt, it was Somerville and slag that sowed the seeds of the revolution at the turn of the century ; slag demonstrated the potentialities that lay latent in even the most unproductive of swards and grazings. What a sorry England it was in those days ! During 1909–11 I had intimate experience of the Cotswolds (a typical example of the effects of our agricultural slumbering), then "famous" for its huge acreage in outrun sainfoin leys—fields a mass of golden dandelion and lop-grass.* These were fields long since abandoned from arable and upon which if anything was attempted, it was generally nothing more exciting than throwing down basic slag or other phosphatic manures in the hope that the wretched and gappy medley of plants would settle down to something that would at least look like reasonable " permanent grass".

And so towards 1914. Slag had not, however, been the only "seed" sown ; Gilchrist, with his Cockle Park mixture, was sowing the seeds of wild white clover, of leafy (Akaroa) cocksfoot and of the longer ley. But these potentially fruitful seeds were not gaining ground at the expense of permanent grass. England and Wales entered on World War I in 1914 with over 16 million acres in permanent grass—the highest figure since

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**Bromus* sp.

acreages were recorded ; in 1872 it stood as low as 11½ million acres, and with nobody supposing that the improvement of rough and hill grazings was a practical proposition. The first World War, although leading to a praiseworthy effort in the ploughing up of permanent grass, had no lasting effect in its reduction. We started World War II with 15¾ million acres. The 1914–18 War, and the years immediately after, had, moreover, no tangible influence on increasing the acreage in leys. The only contributions the war made to the momentum of the revolution were to impress upon the observant two fundamentally important facts : (1) that 1,000 acres in rotation (even in long rotation, with longish leys) produced far more human food than 1,000 acres in the very best of permanent grass, and (2) that those permanent grass fields which had been well slagged and well cared for, yielded easily to the plough and almost immediately made excellent arable land.

The New Knowledge From 1919 onwards a great impetus was given to agricultural research by increased Government grants. Regional surveys—soil, ecological, economic and farming—were conducted and amongst other things plant breeding was extended to cover herbage grasses and legumes. We were beginning to see daylight as to the factors influencing the nutritive value of herbage. The extent to which the soils of whole regions were deficient in lime was being accurately recorded. We came to realize that potash, as well as being necessary for particular crops, was unavailable or deficient in the soil over wide and well-recognized regions—this was not appreciated in the 1914–18 war. Every one of these facts had a decided influence on the feasibility of replacing permanent grass with arable based on the ley.

Pioneer farmers were absorbing the new knowledge and thinking hard for themselves. By the 'thirties new and bred strains of grasses were becoming available, at least for experimental purposes, to supplement wild white clover. The enormous waste of nutrients in haymaking was being increasingly recognized ; the idea of making silage was not falling wholly on deaf ears, and experiments in grass drying were bearing fruit. All these tidings were slowly infiltrating into farm practice ; men of daring and enterprise began, in very truth, to break new ground. Hosier was busy on the Downs, Bennett Evans was ploughing on the slopes of Plynlymmon ; here in this district and there in that farsighted men who liked the plough and who objected to miserable permanent grass were embarking upon the long rotation and the ley. The movement was given further momentum by the reseeding experiments at high elevations and on utterly inhospitable land in that remote and rugged part of Wales where previously Johnes of Hafod had shown such indomitable enterprise.*

Then in 1937 came the basic slag and lime subsidies; and finally, early in 1939, that farsighted act of statesmanship, the ploughing-up subsidy. All this must be narrated, because when the second World War came with its dire need, there were enough men (farmers and technical advisers) to arouse enthusiasm and to give a lead in the means and methods of both land reclamation and the type of farming that the war situation demanded. The state of affairs was entirely different to that of 1914 ; now there was an undercurrent of real enthusiasm for the job ; the tractors and implements, as far as they were available, were powerful, reasonably foolproof and sturdy. The result was that by 1941 the revolution in grass was in full flood. It has ebbed and flowed since the epoch-making year 1944, when permanent grass stood at its lowest recorded figure of 9¾ million acres. The acreage has since

*Elizabeth Inglis-Jones. *Peacocks in Paradise*. London, 1950.

risen (to stand at nearly 10¼ million acres in 1950), but the revolution is still going strong and is gaining ground in many important directions.

The Ley for Food and Fertility The present trends of the revolution under the hands of our best farmers are shown by a few figures for England and Wales as a whole. Immediately before the war the area in leys was only about 2¼ million acres. The first effect of ploughing-up was to reduce this to about 1¾ million acres in 1941. Then, as we got properly into the permanent grass, and as the ley came to be appreciated on its own merits, it steadily rose to reach its highest recorded figure—3.7 million acres in 1946, and it still stands at just over 3.5 million acres. The two most significant measures of the extent of the revolution are the decrease in permanent grass (and correlated extension of arable) and the increase in the contribution of the ley to farm grass—defined as the sum of permanent grass and the ley. The significance of these comparisons is greatly accentuated by the growing realization of the value of the ley sod in taking care of soil structure and in providing good material to maintain the humus content of the soil. The ley has its extraordinarily important part to play in maintaining what will have to be a still expanding acreage in arable in good heart. The dual purpose of the ley—to produce feed for stock and to husband soil fertility—is the quintessence of the revolution we are witnessing. This means that acres in grass can be made (in proportion as permanent grass is ploughed out) directly responsible for, say, the production of wheat and of silage, of potatoes and of grazing! Considered in this light, the comparative figures (in percentages) set out below are revealing and full of high promise for the future.

	England and Wales		Scotland	
	1939	1944	1939	1944
	per cent		*per cent*	
Permanent grass of cultivated land	64	40	37	24
Leys of farm grass	12	23	48	54

The comparison is made with Scotland because implicit in the figures is the strong suggestion that England and Wales (still with over 10 million acres in permanent grass) can go a long way yet to increase their arable acreage (with consequential increase in all-round food production—food and feed) without taking liberties with the safety of their soils.

A far-reaching development has been the impetus given—largely due to the plant breeder—to the home production of herbage seeds and to the movement towards a sound scheme of safeguarding (by methods of inspection and certification) the authenticity of the several strains. An immense amount of work has been done to this end by close collaboration between Government officials, scientists, the seed trade, and farmers. A measure of the advances made is given by the state of affairs as to Aberystwyth seeds. Before the war the amount of such seeds actually on the market was no more than a half-hearted promise of good things to come. By 1941, 1,590 acres were devoted to the growing of those seeds under the auspices of an embryo scheme—by 1947 the area had increased to 36,000 acres.

Exact figures for the acreage cut for silage either before the war or at present are not available—before the war the extent to which silage was made was relatively slight. It has been estimated that for Great Britain about 1¾ million tons of silage was made in 1950, which was four times as much as that made in 1948. This in itself constitutes a complete revolution

in grassland husbandry, compared with, say, 1913. Before the war grass-drying could not be regarded as of any great significance in the conservation of grass. It has been estimated that in 1949 there were 650 units (unit=drier producing roughly 4 cwt. of dried grass per hour) producing 150,000 tons of dried grass ; in 1950 this had risen to 875 units producing 220,000 tons. Both the cutting for silage and for grass-drying react decisively on grassland management. In conjunction with a proper use of fertilizers and with good grazing management, they can be made enormously to increase both the yield and effective utilization of nutritious grass-feed per acre.

When we examine individual farms the truly remarkable fact is the number of farmers who have contrived, and are still contriving, as the result of the wholesale ploughing up of permanent grass and derelict land, to produce far more livestock products than formerly on what were tantamount to all-grass holdings, and at the same time to carry great acreages of high yielding cereals and other crops for direct human consumption. It is not as if achievements of this sort are isolated or are met with only on certain classes of land. They stand witness to the magnitude of the revolution in districts as different, one from the other, as the fat lands of the Midlands, the Chalk Downs and the Welsh Border country.

The Modern Approach Looking more closely into changing methods, perhaps the most striking points are : the extent to which some farmers have virtually abandoned haymaking and turned to ensilage, the large acreages many farmers devote to herbage seed production, the continuous experimenting by farmers in the matter of seeds mixtures for their leys ; and in many respects most interesting of all are the rapid changes in grazing technique. The electric fence has been a potent force in this latter respect, first assisting alternate and on-and-off grazing and now opening almost limitless possibilities in the direction of strip grazing. Herbage seed production has fitted in well with ley-farming rotations, and there is evidence to suggest that the rich root growth from these crops is of high value in maintaining the humus content of the soil. Views on seeds mixtures change with intriguing rapidity from farm to farm and on the same farm from year to year. How different this is to the conditions at the turn of the century, when most farmers had no knowledge of what they sowed and seemed to care less—so long as the seed was cheap ! Ultra-simple seed mixtures and low seed rates have been responsible for teaching farmers more about grass than any other factors. Today grass is not just "grass", nor is cocksfoot just "cocksfoot" ; farmers now talk about strains of grasses as aptly and knowledgeably as they do about the points of stock. They want their strains pure ; they help to grow them and they can get them, and because of their own efforts they deserve the best. The real point is that we have finished with the idea of one omnibus mixture (even a good one like the Cockle Park) suitable for the whole of a farm, for every requirement and for every farmer. Adroit farmers by an adroit use of contrasting and different mixtures are extending the length of their grazing season—wide-spaced drills are already, and with justice, being talked about, as further and highly promising aids. When we realize that reclamations and improvements are now being seriously started on the more suitable areas of our hill lands and that large acreages are amenable to the more drastic methods involving the plough, a rotation and re-seeding, we have the full measure of the gathering momentum of the revolution with its ever extending sphere of influence.

All these changes and possibilities, coming at a time when farming is an active and not a passive pursuit, not unnaturally have brought both thought

and action into a state of flux. This is all to the good, and although the ley and the new methods may be held suspect (rightly or wrongly) for certain untoward happenings, no great harm has befallen to offset increased production. A start had to be made somewhere, and if methods of producing and converting lush grass have outstripped knowledge as to the animals' metabolic functioning in respect to same, that is only temporary.

Looking to the future, it can be said with some assurance that the greatest enduring value of the revolution in grass is the way in which it has helped, and is helping, to bring together, in intimate collaboration, the farmer, the plant scientist and the animal scientist. With rapidly increasing departmentalized knowledge and ever-greater enterprise on the part of farmers in exploiting new discoveries and new ideas, the whole future and stability of our farming systems are likely to depend upon the heightening intimacy of that collaboration.

SCIENTIFIC DEVELOPMENTS IN ANIMAL HUSBANDRY

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With increasing efficiency in agriculture, one of the first needs is to improve the quality of farm stock. To this end, unremitting research in animal husbandry points the way to better and specialized breeding, and to more economic and better feeding.

SCIENTIFIC developments in animal husbandry have not only been brought about by direct investigation of agricultural problems by scientists, but indirectly by scientists who have made discoveries and formulated theories which have later been applied to domestic animals. Discoveries which were made some time ago can be evaluated as to the importance of their effects on the practice of agriculture, but it is very difficult to assess the value of recent scientific work which has not yet been widely tried out in practice, and accordingly the latter will be only briefly referred to here.

Nutrition It was Lawes and Gilbert at Rothamsted who first investigated the changes in the composition of the animal during fattening and the value of different feedingstuffs for this purpose. They demonstrated the greater efficiency of conversion of carbohydrates than proteins for this purpose. After a lapse of years, Wood and his successor Woodman at Cambridge, and Crowther at Leeds, adopted a method of rationing animals based on " starch equivalents," and from many experiments made throughout the country built up tables showing the nutritional value of the different feedingstuffs used in this country. These have proved invaluable in rationing animals for maintenance and for production. Protein requirements were also worked out, and later research showed how the level of protein intake necessary varied for different classes of livestock ; for example, the importance of protein feeds for young animals in the rapidly growing stage, for dairy cows and for laying hens.

After the first world war and the shortages of concentrates that it caused, Wood and Woodman at Cambridge investigated the quality of roughages and drew attention to the high protein and mineral and low fibre content of young grass as compared with hay made at a later stage of growth. From these results they suggested the system of grass drying which is now so widely used. Using the calorimeter as a means of investigation, Wood with Capstick and Deighton also pointed out how the normal food intake of the young pig about the weaning period was so close to maintenance requirements that little nutriment was left for growth. This led to the creep feeding of concentrated food to sucking pigs, which has speeded up the time and so reduced the amount of food required to reach fattening weights.

At Aberdeen, Orr drew attention to the necessity for minerals in the diet, particularly for calcium and phosphorus in the rations of dairy cows and growing animals. Later experiments showing the harmful effects of the absence of certain trace elements such as iron, copper, iodine, and cobalt, drew attention to the necessity for these in what was otherwise a good ration. The discovery of accessory food factors, or, as they are now called, vitamins, by Hopkins at Cambridge in experiments on rats, has had a profound effect on the nutrition of both man and farm animals, particularly the pig and fowl. This initial discovery has led to a large number of such substances being found and manufactured for use in animal feeding, and has provided the remedy for what at one time were thought to be obscure diseases. More recent experiments on the importance of the plane of nutrition are referred to below.

Meat Production As mentioned above, Lawes and Gilbert at Rothamsted were the first to investigate the scientific principles underlying meat production ; these experiments were mainly concerned with the composition of the carcass in cattle, sheep and pigs at different stages of fattening. Later, after the first world war, when plentiful supplies of meat were coming in to this country from overseas, the factors affecting the quality of meat became important and this was accordingly investigated at Cambridge. The changes in the body conformation which took place as the young animal grew up were worked out in early- and late-maturing types, and it was shown that from the butcher's point of view the early-maturing type was the animal which changed quickly in its composition and the proportions of its body. The young animal at birth is all head, legs and bone, but has a small proportion of loin and fat, which develop as the animal grows. The reason for this is that the rate of growth in bone and head reaches its maximum early in life, followed by muscle and legs and later by fat and loin. It was found that these age changes in body composition and proportions could be controlled by the plane of nutrition on which the animal was reared. For example, a high plane of nutrition when the pig is young causes growth in length of body, and rationing the food towards the end of the feeding period cuts down fat and so gives a good bacon pig ; the reverse, i.e., poor feeding when young and heavy feeding later, gives a short pig which is much too fat to meet the consumer demand and which, moreover, consumes more feedingstuffs to produce 200 lb. live weight than the former.

Similar experiments with beef cattle showed the importance, for economical production, of high plane feeding during the first eight months of life. The young animal is a much more efficient converter of feedingstuffs into meat than is the old animal. Wood and Newman found, for example, that while it took only 11¾ lb. of dry matter in the feed to produce 1 lb. of saleable

beef from a 1½-year-old steer, it took 22½ lb. of dry matter to produce the same quantity from a 3-year-old steer.

In modern methods of meat production with early-maturing types, the animal for much of its life is dependent on its mother for sustenance, and this is particularly so with sheep and pigs. Attention was therefore directed at Cambridge to the effect of the nutrition of the mother on the rate of growth of the offspring, and it was found that by feeding the ewe well during the last eight weeks of pregnancy, not only were the lambs larger at birth, but also they grew much faster afterwards, due to the better developed udder and milk supply.

The growth studies at Cambridge also directed attention to the factors which controlled the partition of the nutrients to the different tissues of the body after they had reached the blood stream. This depends on the rate of metabolism of the tissue, early-maturing tissues such as brain and bone having priority over late-developing tissues such as muscle and fat under low plane conditions of nutrition. For this reason most animals should be reared on a high plane of nutrition if their inherent genetic qualities for production are to be developed.

Another application of the growth studies on farm animals has been that of the points scale system of judging the suitability of carcasses for market. Butchers pick out an ideal carcass, measurements are taken of muscle, fat and bone in different places and then, with a knowledge of how these tissues grow, the best system of growing the animal to meet this market by changes in nutritional plane at different phases of its life can be worked out. Such a points scale can also be used for the selection of breeding animals for meat purposes through progeny tests.

Milk Production At Reading, Stenhouse Williams's research laid the foundation for a clean milk supply both as regards freedom of the cows from disease and in the methods adopted for milking and handling of the milk to the consumer. This had a great effect on the building up of a consumer demand for milk. Both here and at the Hannah Dairy Research Institute later, much scientific work was done to assist the cheese-making and dried milk industry.

After the first world war, when the dairy industry rose to become the most important branch of farming in this country, Sanders at Cambridge applied at that time a new form of statistical investigation (" operational research ") to the problems of the dairy industry. Collecting milk records from two different areas in England, he calculated the effect of different factors on rate of milk secretion. Some of these results, such as the effects of the dry period and service period on yield, suggested laboratory experiments which showed how, towards the end of pregnancy, the mammary tissue of the udder grows in preparation for the next lactation ; this provided the scientific basis for the " steaming up " of dairy cows. His finding, too, of the variation in rate of secretion which occurred at different times of the year directed attention to the value of young grass as a feedingstuff and to the depressing effects of fibre in the ration. The practical application of these scientific facts were extended by Boutflour with very great effect on milk yields throughout the country.

During the second world war, when imported feedingstuffs were cut off and winter milk production had fallen to a very low level, attempts were made at Reading and Cambridge to find out whether the newer knowledge concerning the hormones (activating chemical substances formed from

glands and circulating in the blood) could be used to increase production. It was found that tablets of the synthetic oestrogen stilboestrol, discovered by Dodds in London, when implanted under the skin of non-pregnant cows and heifers, would make the gland tissue of the udder develop and bring them into milk within a few weeks. Heifers found not to be in calf in May and June could be brought into milk for the autumn and winter months when milk was in short supply. There are some defects in the method, however, and although it is useful in an emergency, further work on it is necessary if it is to be generally useful in practice. Another hormone, thyroxin, and its synthetic substitute, iodinated casein, was found by Folley, working with Kay and others at Reading, to have a remarkable effect in stimulating the milk and especially the butterfat production of cows already in milk, but again there are difficulties in practical application and it is still under investigation to find out what are its long-term effects.

Breeding Charles Darwin, through his theories on evolution and natural selection, and his study of plants and animals under domestication, exerted a most profound influence on all animal breeding practice, while his cousin, Galton, who introduced the idea of " percentage of blood," assisted the animal breeders considerably. Cossar Ewart at Edinburgh investigated many breeders' beliefs held at that time (1895), and among other things showed that there was no scientific foundation for such ideas as telegony, acquired characters or maternal impressions. William Bateson at Cambridge, who disinterred Mendel's laws of inheritance in 1910, started a new phase of development in animal breeding, and this was at once applied by Wood to the inheritance of colour and horns in sheep and by Punnett to poultry. It was Punnett who, together with Pease, first produced a sex-linked breed of poultry which would breed true—the Cambar—and which has been the parent of many new sex-linked breeds of poultry. This has enabled chicks to be sexed at hatching by colour differences and, together with sex-linked crosses between different breeds, has been of great assistance to the poultry industry. In 1920, Crew and his co-workers at Edinburgh started to make many studies on inbreeding and the inheritance of different characters in farm animals, which have been most useful to breeders, and Greenwood made a genetic analysis of the factors affecting egg production and size of egg.

Perhaps the most important outcome of the genetic research which has been undertaken has been to draw attention to the importance of the progeny test, that is for example, to judge the value of a dairy bull by his offsprings' rather than by his dam's yield. Methods for doing this in practice were investigated by Edwards and are now beginning to show results. The scientific facts of dominance and of crossbred vigour have been utilized in practice by the use of colour-marked beef bulls, such as the Hereford (white face) and Aberdeen-Angus (black polled), which impress these characters on the calves got by them from dual-purpose cows in dairy herds. Thus vigorous crossbred calves for beef purposes are obtained without the danger of such beef-bred animals getting mixed up with dairy stock and so lowering the efficiency of the dairy industry.

Indirectly the various studies on growth and milk secretion mentioned above have helped breeders to appreciate the value of suitable environmental conditions, nutritional and otherwise, in developing the genetic characters of the animal, so enabling selection of animals for higher production to be made more easily.

Reproduction It was Heape at Cambridge who, about 1896, realized the importance of the losses caused by sterility in the flocks and herds of the country and started the scientific study of reproduction and of artificial insemination. Following him, Marshall, among many other studies which were of importance to the breeders, first showed how the lambing percentage of ewe flocks could be considerably increased by flushing them with extra feed at the approach of the tupping season. He also showed how the seedy-cut which caused such losses in the bacon industry, was due to black skin pigment penetrating the mammary glands. Under his guidance at Cambridge and elsewhere, studies were made of the normal processes of reproduction in cattle, horses and sheep, which have formed a basis for dealing with problems of sterility. For example, a knowledge of the time the egg is shed in relation to the end of heat—24–48 hours before in the mare and 14 hours after in the cow—has been most useful in timing matings, for the sperm and egg do not live long. Recently the effects of hormones on these processes have been investigated and a measure of control has been obtained over them. For example, long heat mares which are difficult to get in foal may be caused to shed their egg in about 30 hours by injections of Prolan after mating, and so have a high chance of becoming pregnant. Other effects of hormones, such as the ripening of many eggs by the cow after injections of pregnant mare serum hormone, open up possibilities for the future by the production of twins in beef cattle and the transplantation of beef eggs into dairy cows, but these investigations are still in the experimental stage. Another result which is still in the experimental stage in farm animals, is the control of the breeding season in the sheep and horse by changing the hours of darkness and daylight ; this is already a practical proposition with hens and ferrets.

Perhaps the most important outcome of these studies on reproduction has been the development of artificial insemination, which is doing so much to enable the small dairy farmer to breed good cattle without a large outlay of capital. Worked as it is in conjunction with the use of proven bulls, it should prove a most potent method of improving the commercial cattle of this country. The first successful long distance transport of semen, between this country and Poland, was made by Walton with sheep in 1935.

Animal Behaviour Within the last few years a new scientific approach to problems of animal husbandry has been developed at Compton, Drayton, Aberdeen and other places. It seeks to give a scientific basis for the stockman's art in managing animals by studying their habits and responses to different conditions. Already it has been most useful in overcoming many of the inhibitions to service by bulls due to bad systems of management, and by studies of the grazing habits of animals has suggested methods of increasing their food intake and so production from grassland.

THE MARCH OF VETERINARY SCIENCE

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It is impossible in a short article to describe the many developments in veterinary science, or even to refer to the many advances in our knowledge appertaining to the maintenance of animal health and the control of livestock diseases. Sir Thomas Dalling here deals only with some of the methods now in use for the control of diseases of major importance among cattle, sheep, pigs and poultry.

ALTHOUGH much could be written on the methods adopted for the prevention and treatment of diseases of animals as practised during and since ancient times, it is within recent years that veterinary science has attained full stature. Side by side with this advancement has proceeded veterinary research work, with the result that throughout the whole world it is now possible to adopt protective and curative measures which go far to control some of the highly infectious animal epizootics which have caused such high economic loss.

From the view point of economic importance the horse has been replaced by the food-producing types of livestock, and therefore greater attention is now being given to the welfare of cattle, sheep, pigs and poultry: their major diseases have been studied, the causes ascertained and methods of control developed and put into practice.

The country was freed from some of the major epizootics many years ago and happily, with the maintenance of strict precautions, has remained free. From time to time, however, a serious exotic disease makes its appearance, due largely to the entrance of the infectious agents in imported material ; thus the occasional outbreak of foot-and-mouth disease, and the recent occurrences of fowl pest (Newcastle disease). Such diseases are dealt with promptly by a slaughter policy, coupled with restrictions on movement of livestock within defined areas. These methods are, generally speaking, highly satisfactory in preventing such diseases becoming endemic in this country, and there should be no question of their abandonment unless unforeseen circumstances should arise.

There are, however, in this country a number of diseases, endemic in nature, for which such drastic treatment is either impossible or uneconomic : for their control, other methods have been devised. The methods have been arrived at from the results of research work, followed by field trials and, although much of the necessary research work was of an applied type, full advantage has been taken of basic researches carried out by workers in many branches of science.

Cattle In cattle, the incidence of bovine tuberculosis has been reduced, and such steady progress in its control has been made that it has been found possible to bring into operation an "area" scheme, in which parts of the country will be freed from bovine tuberculosis, leading in due course, it is hoped, to the eradication of the disease from the whole country. The control of tuberculosis has been possible only by the use of the tuberculin test, the operation and interpretation of which have been greatly improved in recent years. Tuberculin can now be standardized with much accuracy since the introduction of the purified type of the product (P.P.D.), and, while it is

known that agents other than the causal micro-organism of bovine tuberculosis sensitize cattle to tuberculin and therefore give rise to reactions following the injection of tuberculin, the use of two tuberculins—mammalian and avian—has gone a long way towards the differentiation of sensitivities arising from bovine tuberculosis and other infections in cattle herds. It was thought at one time that it might be practical to immunize cattle against bovine tuberculosis : while there is much evidence to indicate that an immunity can be established by the use of agents such as the B.C.G. strain of the tubercle bacillus and the vole strain of the micro-organism, experience has shown that other methods give quicker results in ridding herds of the disease and are therefore more economical.

Brucellosis, caused by *Brucella abortus*, is confined to cattle in this country. In some other countries the *Br. suis* and *Br. melitensis* micro-organisms are commonly found and produce active disease primarily in pigs and in goats and sheep, respectively. We are free from such infections. The control of brucellosis has been greatly improved by the use of the blood-agglutination test and by special types of vaccines. The blood-agglutination test is highly specific and reliable, provided accurately standardized agents are employed and the results carefully interpreted. Many herds have been freed from the infection by the application of the test, and when conditions can be applied to prevent further introduction of infection, such herds can be maintained free from the disease. Because of the high incidence of brucellosis throughout the country and the ease with which infection can be introduced into a free herd, vaccination as a means of control is now very widely practised. The highest degree of immunity follows the use of vaccine composed of living organisms of high virulence. Because of the risk of setting up permanent infection from the use of such a product, other types of vaccine have had to be employed. The now world-famous American Strain 19 vaccine is for the present the agent of choice : the micro-organisms composing the vaccine are living but are in such a state of attenuation that they are incapable of setting up infection but have a high immunizing value. Non-pregnant females are the subjects of vaccination, and there is reason to believe that a single dose of the vaccine injected into heifer calves between the ages of four and eight months gives rise to an immunity which remains satisfactory for at least four pregnancies. It is to be remembered, however, that as with all immunity artificially induced, that arising from the injection of this vaccine is relative, and can be overcome by exposure to massive infection. Experience has shown the necessity of adopting measures to prevent such infection along with vaccination and not to rely solely on the vaccine to control the disease.

There is much evidence for the successful control of brucellosis by a vaccination policy : not only are actual abortions due to the infection prevented but infertility associated with the infection is also controlled. This has led to a study of other causes of abortion and infertility, some of which, though recognized in the past, have now been shown to be of great economic importance. Trichomoniasis, caused by the parasite *Trichomonas foetus*, is now better understood, and methods for its diagnosis have been improved. The practice of artificial insemination, using semen from healthy bulls, has gone a long way to eradicate this infection from herds throughout the country. The part played by the micro-organism, *Vibrio foetus*, in causing abortion and infertility is at present the subject of intensive research work : its occurrence is now known to be much more widespread than was commonly believed and methods of diagnosis have been worked out.

Bovine mastitis is now better understood, following the evidence that the disease is associated with the presence and multiplication of micro-organisms

in the udder. Different micro-organisms are found and give rise to different types of the disease. Most attention has been given to the sub-acute or even chronic diseases in which *Streptococcus agalactiae* in the udder plays an important part. Following attempts to rid the udder of infection by the oral administration of agents, the modern method of treatment is to inject into the udder through the teat canal such medicaments as penicillin, streptomycin and aureomycin in adequate dosage and often enough to maintain a level of the agent in the udder sufficient to destroy all the streptococci. The base in which the agent is incorporated is also of importance to obtain the best results. Field trials have proved the value of this method of treatment, but stress must be laid also on the need for good husbandry and hygiene to prevent reinfection. An udder freed from *Streptococcus agalactiae* infection will remain free, unless further infection is introduced through the teat canal. With other infections, e.g., other types of streptococci, staphylococci, Corynebacteria, etc., maintaining the udder free from infection is more difficult, for the respective micro-organisms are found in tissues of the body other than the udder which they may reach from such sites if the resistance of that organ is reduced—as occurs from injury, rough and careless milking operations, overstocking, chilling, etc.

Johne's disease and foul-in-the-foot are other diseases of cattle in which progress has been made. In the former there is evidence of control by vaccination ; the latter is quickly cured by intravenous injection of some of the sulphonamide products.

A good deal of attention is now being given to diseases of calves, especially scours. The types of micro-organisms associated with the condition are now recognized, and the value of colostrum in preventing the infections has been well substantiated.

Sheep In sheep, the most important development is probably the recognition of their high susceptibility to anaerobic bacteria, especially those which, under certain conditions, invade the mucous lining of the digestive tract, there multiply rapidly and produce toxins in large amounts, giving rise to the group of diseases classed as enterotoxaemias. Early work on lamb dysentery opened up the field of investigation into the *Clostridium welchii* group of anaerobic micro-organisms, and research work demonstrated the different types of toxins which could be produced and are associated with different recognized diseases of lambs and adult sheep. It was this work also which led to the method of immunizing young animals by vaccinating the mothers before and during pregnancy. The immune bodies generated in the mother are not passed to the foetus *in utero* but become concentrated in the colostrum and are absorbed through the intestinal wall following the suckling of the young animal soon after birth. Braxy, caused by *Clostridium septique*, led the way to the development of anacultures as vaccines for the prevention of anareobic infections The most recently discovered anaerobic infection in sheep in this country is that due to *Clostridium oedematiens*, which causes " black disease," a condition known in Australia for many years. This is not a straightforward infection ; before it gives rise to the disease, a second factor is necessary : the micro-organisms are found in the liver but remain inactive until the immature liver flukes have damaged the liver sufficiently to stimulate multiplication and toxin production by the micro-organisms.

Diseases in sheep associated with malnutrition have also been widely studied. There is now ample evidence that sheep in some hill districts fail to obtain a sufficient supply of essential major food elements at certain times,

especially during pregnancy, and that this deficiency may have an important bearing on diseases of pregnancy. Minor or trace element deficiencies are also recognized and the effects on health and growth of some of them are now understood. A deficiency of cobalt occurs in some parts of the country: gross deficiencies are reflected in the occurrence of "pining" in sheep, lesser deficiencies are associated with poor growth and under-development. Supplements of cobalt can be given in the form of salt licks, injections or by the application of cobalt to the deficient soil as a dressing. Copper deficiency in sheep is recognized in the disease "swayback" in lambs. In this condition the deficiency occurs in the foetus *in utero*, giving rise to a reduction or total absence of the white matter in the central nervous system. Although the diet of the pregnant ewe may contain apparently adequate amounts of copper, the necessary amount fails to reach the developing foetus. The condition can be overcome by feeding a supplement of copper to the pregnant ewes.

Louping-ill in sheep can now be controlled. It has been satisfactorily demonstrated that the disease is caused by the presence of a filterable virus in the central nervous system, that the infection is transmitted by the tick *Ixodes ricinus*, and that the virus can persist through some of the developmental stages of the tick. Apart from ridding land of ticks, methods for which are being studied, louping-ill can be controlled by the injection of vaccine prepared from infected sheep tissues, before the season of tick activity.

During investigations into louping-ill a hitherto unrecognized disease was found—tick-borne fever, caused by a rickettsial-like agent. This blood parasite, transmitted by ticks, gives rise to a high temperature in infected sheep and, though it may not cause death, it may act as a predisposing agent to other disease conditions, e.g., pneumonia, and it may induce abortion.

Scrapie in sheep is now known to be associated with a filterable virus which has rather peculiar properties. The incubation period may last for many months, and the virus can withstand conditions which destroy many other viruses causing diseases in livestock and human beings.

The most recent work on sheep diseases concerns enzootic abortion, a condition prevalent largely in the area of the Scottish-English border, although present in other parts of the country. For many years the cause was unknown: recently, however, the disease has been shown to be an infection of the placenta with a small rickettsial-like body, the presence of which in susceptible sheep may give rise to abortion. There are encouraging indications that an immunity can be set up by artificial means.

Pigs New methods for the control of some diseases of pigs have also been found. The introduction of crystal violet vaccine offers a means of both control and prevention of swine fever, whereas formerly there was little to be done until an outbreak was diagnosed, when it became economic to slaughter affected and in-contact animals. This vaccine is composed of blood and other tissues from artificially infected pigs to which the dye, crystal violet, and glycerine are added. Following exposure to incubator temperature for some weeks, the resultant product is no longer infective but is highly antigenic, and in moderately small doses sets up a high degree of immunity in susceptible pigs for at least one year.

Studies have been made on respiratory diseases of pigs, and it has been shown that at least two causes may give rise to affections of the lungs: one is the virus already recognized as causing piglet influenza; the other, another

virus is responsible for pneumonia in pigs but which appears to be unrelated to that associated with piglet influenza. There is evidence that the virus of piglet influenza is related to one of the types of human influenza virus, and thus the pig becomes important as a possible reservoir of the human influenza infection.

The association of micro-organisms, especially of the Salmonella group, with diseases of the digestive tract and the effect on the health of pigs has been studied. We have now a better understanding of the effects of the presence of these organisms in the intestine on the growth and well-being of pigs.

Swine erysipelas, which is found on many pig premises and which infects pigs particularly during the summer months, can be satisfactorily controlled by the use of anti-swine erysipelas serum, with or without vaccine, composed of the living causal micro-organism. A new development is the use of the living "rough" strain of the bacillus as a vaccine, without the simultaneous injection of anti-serum. Laboratory tests have shown clearly the high immunizing properties of this product and its complete safety for susceptible animals.

Poultry For some years, research into problems of poultry health and disease has been encouraged, with the result that the control of some of the important diseases is well advanced. Noteworthy is the prevention of pullorum disease (B.W.D.) in which adult carriers of the infection can be identified by the blood-agglutination test. An important modification of the test has been introduced, whereby it is carried out on the farm and the results are obtained within a matter of minutes.

Salmonella infections in poultry, causing losses of chicks and growing stock, are prevalent in some areas. Different types of salmonella are known to infect poultry, and much work has been done on their differentiation. Blood-agglutination testing has not proved entirely satisfactory for the detection of adult carriers of these infections ; their control is now largely by fumigation of the eggs before and during incubation. Our knowledge on fumigation has developed considerably, until now fumigation is a routine practice in many hatcheries.

Some other diseases of poultry have now been brought under control, e.g., fowl pox, by vaccination with living pigeon pox virus, and coccidiosis by the use of drugs of the sulphonamide series. The disease, fowl paralysis (leucosis complex) has been shown to be infective ; young chicks are highly susceptible and, after infection, may fail to show symptoms for many months. The rearing of young stock apart from adult birds helps to prevent spread of the disease.

Parasites of Sheep and Cattle Research work into parasitological problems has resulted in better control of some of the diseases of economic importance associated with parasites, external and internal, in all types of livestock. The introduction of benzene hexachloride into dips used for the control of sheep scab, ticks, sheep maggot fly, etc., has proved of high value, and the new types of dips are gradually replacing the old.

The use of phenothiazine as an anthelmintic, together with different methods of husbandry, has now controlled parasitic gastro-enteritis in sheep to such an extent that they can be kept in good health under conditions

which formerly were impossible. In connection with parasitism of the alimentary tract, the association with deficiency in trace elements, e.g., cobalt, must be borne in mind.

Liver fluke infestations in sheep and cattle are now better understood, especially concerning the distribution of the disease and the variation in intensity from year to year. Work on the habitats of the intermediate host—the snail (*Limnoea truncatula*)—has shown why the incidence of liver fluke disease may be higher in some seasons than in others. It is now possible to demonstrate to farmers the likely places on the farm where these snails are to be found, to treat the area and so kill off the snails.

The above notes indicate some of the developments in veterinary science during recent years. With the encouragement given to research work and the efforts now being made to study the many problems affecting the health of livestock, we may be confident that further developments will accrue as scientific investigation advances.

THE CONTRIBUTION OF PLANT BREEDING TO CROP IMPROVEMENT

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British agriculture owes a great debt to the work at Cambridge of Dr. Rowland Biffen, who, following the principles evolved by Mendel, virtually laid the foundations of agricultural crop improvement in this country. Other British plant breeders have followed worthily where he led, so that today the farmer's choice of varieties is wide enough to cover all conditions of soil and climate

It is often assumed that there was little conscious improvement of crop plants before the advent of rationalized and scientific methods of plant breeding which developed after the re-discovery of Mendel's famous paper on the inheritance of certain characters in peas after controlled hybridization. This, however, is far from being the case, and there are many examples of valuable contributions by non-scientific men in the eighteenth and nineteenth centuries which had considerable repercussions on British agriculture. Most of these contributions were, in the earlier periods, the result of chance selections, as for example, the production of Potato oats in 1788, and Sandy oats in 1824, both of which can be said to have originated from the keen observation of farm workers.

Before Mendel Such comparatively haphazard methods of improvement obviously could not persist, and sooner or later systematic selection was sure to have superseded it, once the possibilities of selection were realized. However, other important improvements, such as Chevalier and Goldthorpe barleys, and probably Squarehead wheat (the origin of Squarehead's Master wheat is not known for certain, but it may have had a similar origin) also resulted from chance selections in the nineteenth

century, and opportunism, combined with perspicacity, were giving great rewards. Possibly the first man to practise single plant selection as a method of crop improvement in this country was Le Couteur, who was responsible for stimulating Shirreff to undertake such work. Shirreff practised systematic selection principally in oats and wheat and was instrumental in introducing a number of improved varieties, including Hopetoun and the " Fellow " family of oats, as well as Old Lammas and Bearded Red wheat. Another nineteenth century selector was Hallett, who systematically isolated improved lines from established varieties of cereals, while Paterson, Clarke and Findlay were working on potatoes with such success that varieties such as Victoria, Magnum Bonum, Epicure, British Queen and Up-to-Date were given to agriculture.

The story is by no means exhausted with these examples of the work of the pre-Mendelian selectionists, but it is necessary to mention also the hybridists of this time, who knew nothing of Mendel or laws of inheritance. Thomas Knight, who worked in the eighteenth and nineteenth centuries, was probably the first man to use systematic hybridization in plant breeding : he was certainly the first man of whom there is record who hybridized wheat in this country. Both he and Shirreff realized the importance of hybridizing for producing new combinations of hereditary characters, but the credit of producing the first hybrid wheat for the market is probably due to Raynbird with his Raynbird's Hybrid. However, Garton was also a successful nineteenth century hybridist, the oat variety Abundance being his production, and Findlay was working with hybrid potatoes.

Our Indebtedness to Biffen All these crop improvers were without scientific training or knowledge as these are recognized today, and most of the work was very empirical. It was not until the biology of sexual reproduction was completely understood, and knowledge had been gained of chromosomal behaviour and of character segregation in hybrid populations, that there was really a scientific basis for breeding. The significance of this knowledge cannot be over emphasized, and it soon became possible to introduce breeding methods which eliminated much of the pre-Mendelian haphazardness.

It was largely owing to the academic researches of Biffen at Cambridge that the genetic knowledge resulting from Mendel's work on peas was applied to agricultural plant breeding in this country, and subsequently also, in many other countries. Biffen started his investigations with the avowed intention of finding out whether " Mendel's now well-known law of inheritance applied to other plants than the various kinds of peas he used in his experiments," and in 1904 Biffen published his first paper on hybridization in wheat and barley. This demonstrated Mendelian inheritance in these crops, and Biffen was quick to follow up his scientific investigations by a ready appreciation of the practical application of the new knowledge to plant breeding and crop improvement. By 1907 he was describing " modern plant breeding methods " which owed their origin to genetic knowledge. As a result of these " modern methods," which consisted essentially of obtaining recombinations of desirable heritable characters in the offspring of parents chosen specifically for the purpose, Biffen was able to contribute to British agriculture the well-known wheat varieties Little Joss and Yeoman, which have remained in cultivation to the present day—a period of over thirty years, which is an exceptionally long time for any hybrid variety.

Biffen's work will always be considered as classical because it not only demonstrated the validity of certain Mendelian precepts, but it also laid the foundations of post-Mendelian hybridization as a means of crop improvement. The scientific study of the inheritance of important agricultural and economic crop characters had shown that such characters were subject to hereditary laws, and for the first time it became possible to plan rationally programmes of breeding based on hybridization, and to handle the resulting hybrid progenies with a basis of analytical knowledge that had previously been wanting. This was the great advance on the pre-Mendelian efforts to improve crop plants by hybridization ; it now became possible to establish and develop techniques of breeding according to the reproductive biology of the crop and the type of improvement sought. For the first time the techniques of selection were based on scientific knowledge, and the breeder was able to substitute in some measure an orderly synthesis and analysis for what had, for the most part, been a venture fraught with uncertainty.

It is a matter of considerable importance that Mendel's original work on inheritance, and Biffen's application of it to crop plants in this country, were carried out with self-pollinating annuals, and it was largely in this group of crops—especially the cereals—that the great improvements in crops were initially made in this country. During the first two decades, in addition to Biffen's great contribution with his two wheats, other British breeders were effecting striking improvements in our grain crops. Little Joss wheat had shown the possibilities of introducing the blood of a foreign wheat in order to obtain disease resistance, in this case Yellow Rust resistance ; Yeoman similarly had one foreign parent—Red Fife—and for the first time a baking quality wheat was available to growers, though Yeoman showed other desirable features, such as higher yield and stronger straw than the then commonly grown varieties.

In barley, similarly, considerable advances were made in the agricultural and economic characters of the crop by the introduction of the hybrid varieties Spratt-Archer and Plumage-Archer, which showed a considerable advance in combined field characters and malting quality on the varieties then in cultivation. Although other new varieties of malting barley were marketed round about this period, none achieved the fame of these two hybrids, but varieties such as New Cross, Standwell, 1917 and Golden Archer have made useful contributions.

Over this period, however, there was a great increase in the number of new oat varieties, particularly those suitable for spring sowing, and mention need only be made of such varieties as Marvellous, Supreme, Yielder and Record to name but a few, to realize the importance of the plant breeder's work. It is interesting also that at this time the variety Bountiful, which was the first hybrid oat for which winter hardiness was claimed, became popular, although it is now recognized as being more suitable for spring sowing.

Cereals The more recent contributions to cereal growing in this country by British plant breeders have continued to cover a wide range and to illustrate the importance of hybridization as a means of crop improvement. The baking wheats Holdfast, Warden and Redman, and the "weaker" wheats Steadfast, Victor, Pilot, Squarehead II and Hybrid 46 are illustrative of the type of advance made with an ever-increasing awareness of the growing importance of the requirements of more intensive farming and the demands of the combine harvester. The varietal position in barley has remained

relatively more stable, particularly in the spring malting types, where the only important contribution has been the introduction of the early-ripening variety Earl, which was selected from Spratt-Archer. A new departure in malting barleys was achieved by the marketing of the winter-hardy hybrid, Pioneer ; while the six-row winter hybrid Prefect, and the spring-feeding hybrid Camton were also the first of their types to be introduced.

Of wider application to British agriculture as a whole have been the changes in the new oat varieties. The two outstanding developments in policy have been first, the very obvious establishment of regional, or even of national, breeding programmes ; and secondly, the great advances made in the production of improved winter varieties. Although winter oat breeding has been confined to England and Wales, spring oat breeding has been intensively conducted in Scotland and Northern Ireland also, thereby resulting in the production of varieties tending to have a closer regional adaptation to climate, soil and local requirements than has hitherto been the case. The consequence of this policy has undoubtedly been a considerable improvement in yield and standing ability of the oat varieties available, though it cannot be said that in many cases there has been a corresponding improvement in feeding quality. Some of the better known contributions to spring oat cultivation are Onward, S.84, Maldwyn, Milford, Elder, Early Miller, Craigs Afterlea, Stormont Arrow, Stormont Kern, Stormont Grandee and Stormont Iris, all of which show advances in certain characters over older varieties, and many show adaptation to particular growing conditions.

One of the important changes in oat cultivation in England and Wales particularly, has been the comparatively recent greater proportion of winter oats grown by farmers. This has been due entirely to the improved varieties available, so that instead of the old Grey Winter being virtually the only choice for winter sowing, there are now Picton, S.81, S.147 and S.172. Each of these hybrid varieties shows superiority over Grey Winter in particular characters, principally that of yield and straw, and winter oat growing has consequently been placed on an entirely different footing.

Potatoes The ever-changing picture with regard to potato varieties cultivated in this country, with the very large number of synonyms that has been characteristic of this crop, makes any concise account of improvement unusually difficult. Apart from the usual desirable improvements in yield and quality, the position has always been complicated by the comparatively ephemeral nature of potato varieties, due primarily to progressive disease infection. There are, however, certain landmarks and trends since the turn of the century which indicate the great value of the plant breeder's efforts to the maintenance of the vital position of the potato crop in British agriculture. For example, the introduction of the variety King Edward in 1902 marked a new level in culinary characters of the potato, while the marketing of Majestic in 1911 has since proved to be an historic occasion because this variety has continued to the present day as one of the most widely grown of the maincrops. In the same year Arran Chief was marketed, an event of importance not only since the variety showed itself to have some resistance to late Blight, but also because it proved to be only the first of many varieties—Arran Comrade, Arran Banner, Arran Consul, Arran Crest, Arran Peak, Arran Pilot and others—raised by the same breeder. The series of "Arran" varieties, many of which were raised by hybridization, is rivalled only by the "Ulster" varieties, the most widely grown of which is probably Ulster Chieftain. But the contributions of other breeders are of the greatest significance in the varietal

composition of the potato crop today, as the popularity of such varieties as Duke of York, Great Scot, Dunbar Rover, Dunbar Standard and Gladstone testify. But the war against disease in potatoes now demands even more, and attempts are now being made to combat late Blight and certain viruses by breeding. The results to date are the varieties Craig's Snow White, Craig's Bounty and Craig's Defiance.

The achievements so far mentioned in some of the important arable crops have played a vital part in the productivity of British agriculture for something like a hundred years, and work is still going on to try and meet the requirements of an industry which is constantly making new demands if it is to continue to develop in efficiency. Important contributions have been made in other crops, as for example in the maintenance of standards in sugar beet strains, and certain improvements in mangolds and the field brassicas—swedes, turnips and kales. Considerably more attention will need to be paid to some of these crops, however, if the best is to be obtained from them by crop improvement.

Herbage Plants But apart from the major cereals and potatoes, undoubtedly the outstanding achievement of plant breeding in British agriculture during the last twenty years is the work that has been done on herbage plants, largely as the result of the pioneer researches of Stapledon and his colleagues. The concept of nationality, indigenousness and local adaptation of herbage plants, with its importance and significance to agriculture, owed much of its general application to grassland improvement to the investigations of British scientists. Subsequently, the development of bred strains and their incorporation into grassland husbandry, with the development of the proper status of the temporary ley, may be said to have amounted to a major revolution, both in breeding and in farming practice.

The first stocks of bred herbage plant strains were made available to the seed trade in 1931, and the hay, hay-pasture and pasture strains of perennial ryegrass, cocksfoot and timothy which were released in the first ten years or so have for the most part become established in the agriculture of this country. In addition, the production and release to farmers of S.100 white clover, with also the improved strains of wild white clover, medium-flowering and late-flowering red clover have completed the picture for the major herbage plant species of the country. It is only natural that there should have been further developments in breeding and a greater consciousness of the significance of strains in herbage plants, and such has been the case. Bred strains have now been made available from several sources, and a considerable diversity of forms is on the market.

But the effect of the first work on herbage plant strains has not stopped with the marketing of bred strains. There has been a great stimulation for the preservation, maintenance and multiplication of local strains of such species as red clovers, wild white clover, perennial ryegrass and sainfoin. In addition, there has been the controlled encouragement for the multiplication of important indigenous "commercial" strains such as Irish perennial ryegrass and Scottish timothy, while the activities of seed growers' associations have been considerably increased. All this has promoted the development of a strain-consciousness in regard to herbage plants which has brought them into line with the arable crops and their improved varieties. The results are of far-reaching significance not only to grassland husbandry, but to agriculture as a whole.

BRITISH FARM MECHANIZATION PROGRESS

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The progress of mechanization of British farming during the past decade is both a tribute to British agricultural engineering firms and to the adaptability and efficiency of the ordinary working farmer and his workers.

A TRUE perspective of the present state of farm mechanization in Britain can be obtained only by viewing it as a process of steady evolution and development. In this short article, however, it is hardly possible to do justice to the present ; so the reader who would have this balanced view must be referred to the history books for an account of the work of the men who invented and introduced new ploughs, seed drills and binders, steam-cable tackle and threshing machines, and the prototypes of a hundred other implements and machines now in common use on British farms. For the same reason, it is necessary to omit most of the first half-century of farm tractor development, and to confine this article strictly to the present and the immediate past. It need only be added here that Britain, which developed so many of the implements and machines of the past, continues to lead the world in many branches of agricultural engineering.

The advanced state of farm mechanization is certainly one of the outstanding features of British farming today. The pace of recent progress is well illustrated by the statistics of tractors used on farms in England and Wales—50,000 in 1938, 101,000 in 1942, 180,000 in 1946, and 295,000 in early 1950. Along with this great increase in tractor power came large numbers of such important equipment as tractor ploughs, tractor cultivators and tractor trailers. At the same time, the use of working horses declined markedly, numbers in use in England and Wales being only 289,000 in 1950, compared with 549,000 in 1939 and the peak figure of nearly a million in the early part of the century.

Reasons for Mechanization Increased mechanization has been due partly to the need to get the utmost out of the land (there is a general trend towards increased yields) and mainly to the scarcity and cost of labour. Labour costs represent the largest single item in the total cost of production (on average, just over one-third), and with the minimum wage level now £5 a week, individual farmers find it imperative to improve output per man-hour by the use of more power and machinery. The approximate effect of the changes in tractor and horse numbers mentioned above was to double the total horse power available per worker in the decade 1938–48.

Great saving of time is made possible by using tractors on the heavier work, and as their versatility is increased, the number of jobs that horses can do better diminishes, until there comes a stage when maintaining both horse and tractor equipment is uneconomic.

An important general effect of increased mechanization has been the creation of improved working conditions. This has been a factor in checking to some extent the tendency for workers to leave the land ; and it creates a feeling of confidence that the farming industry in Britain will always be able to attract the required numbers of workers, and to provide jobs which compare well in wages and working conditions with those of other industries.

One of the aims of mechanization today is elimination of the peaks in labour requirement for work such as sugar beet singling and harvesting, potato picking, etc., which at present necessitate the employment of various

kinds of part-time workers. The problem in Britain is not as acute as it is in some countries, such as Canada, which have a continental climate and a very short season in which field work is practicable ; but it is becoming serious on many farms owing to diminution in the numbers of part-time workers available.

So far as individual farms are concerned, it is often necessary to decide whether the saving of labour achieved by mechanization justifies the investment of additional capital on equipment. For example, there is no doubt that a mechanical sugar beet harvester can save a fairly high proportion of the labour needed for harvesting beet ; but it is not always easy for a farmer who has only a small acreage of beet to be lifted, to decide whether it is economic to buy simple two-stage harvesters costing say £150–£200 for the two machines, or a complete harvester costing £400–£500 ; or whether to try and get the job done on contract.

It may be worth while to mechanize a job which comes at a very busy time of the year, but not one which falls to be done at a season when there is no serious labour difficulty. The amount of capital invested per acre in equipment, and the cost of maintaining and running the equipment, are steadily increasing, and it is becoming necessary especially on small farms to consider carefully the economic aspects of further mechanization.

National Aspects The present rate of expenditure on new equipment is of the order of £50 million per annum, a figure regarded by some as being dangerously high. Some economists, unable to find adequate evidence of improved productivity per worker compared with the 1930s, suggest that the time has come to halt the increase in mechanization while farmers learn how to use to better effect the tools they already possess. There is, of course, sound sense in this argument, though many good reasons can be adduced to explain why it is difficult to demonstrate striking increases in the productivity of labour. Fortunately, practically the whole of modern British farm mechanization is based on the products of the British agricultural engineering industry, and the post-war period has seen this industry re-established as the world's second largest exporter of farm machinery. Below, mention is made of a few of the machines which are helping to improve the efficiency of British farming, including some which are finding profitable employment in many other countries of the world.

All-Purpose Tractors the Foundation of Mechanization Progress The foundation of recent progress in the mechanization of field work has been the manufacture on a large scale of really efficient medium-powered " all-purpose " tractors, designed to carry and operate a wide range of direct-coupled or mounted implements. The " three-link " hitch system, similar to that first introduced by Ferguson, but not (apart from the Ferguson tractor itself) employing the Ferguson system of automatic depth control, has been adopted by all the principal British manufacturers of medium-sized wheeled tractors, and there is now good reason to hope that it will be possible to establish agreed standards for the attachment of power-lifted implements to such tractors, so that progress in utilization of this system will not be hindered by any unnecessary lack of interchangeability between tractors and implements. The simplicity and efficiency of the three-link system of implement mounting is steadily receiving wider recognition throughout the world, and it is interesting to see American manufacturers and farmers utilizing this British invention on an ever-increasing scale. The day has gone when a medium-powered tractor merely

had to pull an implement or machine which ran on its own wheels and was attached to the tractor drawbar by a single pin. Henceforth, the tractor must be regarded as a machine tool which can carry and drive an endless variety of equipment, and the slightly more complex hitching is one of the disadvantages which has to be accepted. The total cost of a tractor, equipped with the necessary hydraulic lift and linkage, together with half a dozen typical mounted implements, is less than that of a similar tractor with no power lift and equipped with comparable trailed implements ; and the longer the list of equipment, the greater the saving when mounted implements and machines are employed. Efficiency of operation with mounted implements is also often better than with trailed, and most farmers equipping a farm today would choose mounted implements. Unfortunately, the process of changing over from trailed to mounted implements is apt to be expensive and to lead to inefficient mechanization in the meantime. Most of the leading tractor manufacturers now offer a choice of petrol, paraffin and Diesel engines, and the Diesel is becoming popular in spite of its high initial cost.

Tillage Implements The substitution of mechanical for animal power in farming has had surprisingly little effect on the fundamentals of design of tillage implements. The tractor plough is still easily recognizable as a direct descendant of the horse plough, and the plough is still just as important an implement in Britain as it was a century ago. There are, of course, some parts of the world (for example, the Canadian Prairies) where this implement is no longer used, having been replaced by disc implements which work the soil only to a very shallow depth, but British experience shows the need for ploughing and reasonably deep cultivation to secure adequate weed control. Engine-driven rotary cultivators are now fairly commonly used on horticultural holdings in Britain, and there is a tendency for increased use of tractor-mounted rotary cultivators on such farm jobs as stubble-cleaning. But the most significant recent developments in connection with tillage implements in Britain have been concerned with adaptation of the traditional types of implement for efficient use with modern tractors. An example of such development is the reversible tractor-mounted plough, which seems likely to become increasingly popular, especially for preliminary work on the preparation of seedbeds for root and vegetable crops. The advantages include the elimination of open furrows and some saving of ploughing time.

As with the basic cultivations, so also with jobs such as inter-row and inter-plant hoeing, we find that the business end of the outfit usually has a hoe blade which is intended to work in exactly the same way as if a man were at the propelling end. Nevertheless, Britain has progressed farther than most countries in designing tractors to do the traditional types of cultivation effectively, and in some respects, e.g., the production and use of the self-propelled tool chassis, has produced machines which have no equal in other countries.

Mechanization and Fodder Conservation One of the outstanding trends in fodder conservation in recent years has been the increase in silage-making. This has been the result of demonstrating the palatability and high feeding value of good silage, and of the fact that, with mechanical handling, good silage can be made with ease and almost certain success. British manufacturers have developed a wide selection of green-crop loaders, which are capable of picking up either short grass or heavy green crops from the swath or windrow. Some of the newer

machines are designed for operation at high speed without a man on the load, and these are attractive where large acreages have to be dealt with. At the same time, side-delivery rakes have been strengthened and re-designed for tractor operation, so that both the rakes and many of the crop loaders can be used for both silage and for hay. The simple tractor-mounted buckrake, designed for mounting on the tractor's hydraulic lift, had an immediate success when introduced in 1948, and since that time several thousand farmers have bought and used this cheap device. It is particularly suitable where the silage is made in pits or clamps in or near the field. Investigations of the use of power and labour in silage-making have shown that one man, using a buckrake, can often work more efficiently than a large gang with more expensive equipment.

The use of farm-scale grass driers has increased considerably since the end of the war, and there is now available a range of equipment from a simple single-tray drier with an output of 10 cwt. dried grass per day at a price of about £500, up to plants equipped for grinding and cubing outputs of 8–10 cwt. per hour at prices in the region of £5,000. Artificial drying with hot air provides a reliable method of conserving the high quality herbage that improved leys provide, and though the cost of drying is high the cost to farmers of the final product compares favourably with that of any imported feedingstuffs that are at present available.

In spite of the great increase in silage-making and grass drying, the acreage of grass and clover made into hay is still very much larger than that conserved by other methods. Machines for haymaking—tractor mowers, swath turners, side-rakes, dump rakes, and loaders have been much improved in detail, but the most striking change has been the swing to the use of pick-up balers. These are popular because of the saving of labour and because the baled hay is handy for feeding ; but it cannot be said that the greatly increased use of balers has always resulted in improved quality. For the great improvements in quality that are possible, many farmers are thinking of aids to piking or cocking, and a few are using a system of barn hay drying for completion of the curing process. A few farmers have been successful in obtaining a very high quality product by the barn drying system, and this is a technique which may be capable of fairly wide application in the future. For success, it is necessary to reduce moisture content rapidly in the field in the early stages, and to cart it into the ventilated bay in a barn when the moisture content has fallen to about 40–45 per cent.

Harvesting by Combine Harvesting by combine has rapidly become popular in the main corn-growing areas of Britain, on account of the saving of labour and the fact that losses due to weather risks can be rather less than with the older methods, provided facilities for drying the grain are available when needed. Self-propelled machines, now made on a considerable scale in Scotland, are widely used, both by farmers and contractors. In a normal season, little of the grain needs drying in the dry regions of the southern and eastern counties, but even in these areas there is sometimes difficulty with grain storage if methods of conditioning are not available. The amount of corn threshed at harvest time is now over 1½ million tons, and as the number of combines used increases, so the problems of conditioning and storage become more acute.

Many continuous-action hot air driers are now in use, and since the end of the war two other successful drying systems have been developed. In one of these (the platform drier or sack drier), air heated about 25–30°F. is blown through layers of grain about 8–9 inches thick contained in hessian bags laid over apertures above a system of ducting. In the second system, very

slightly warmed air (temperature rise not over 10°F.) is forced through the grain contained in bins or silos, the air usually being introduced through a porous floor. The drier for grain in bags is capable of dealing with moderate quantities of really damp grain, while the ventilated silo system is suitable for conditioning the grain where the bulk of it can be harvested fairly dry.

Handling of the straw after combining sometimes presents some difficulty, but the use of pick-up balers for this purpose steadily increases, and this method is satisfactory provided the straw is not left too long in the field, and the bales are stored in the dry.

Machinery for Root Crops Britain grows around 1 million acres of potatoes annually, and maintenance of this acreage requires a large amount of labour, especially for harvesting the crop. As a result of a demand for mechanical planters which arose when the potato acreage was expanded during the war, many satisfactory machines have been developed. Some of these are simple and cheap hand-fed devices for use on standard three-row ridging tool-bars, while other types include a variety of tractor-mounted and trailed machines, mostly with semi-automatic feeds in which the potatoes are placed by hand into a series of cups and then delivered by an endless conveyor mechanism into the soil. Some machines have fertilizer attachments, and some are specially designed for planting chitted seed. Fully automatic machines have recently been introduced, but in general the labour requirements of the simpler types of planter are not excessive, and farmers are much more worried about saving labour in autumn.

British potato harvesters are certainly further advanced than those of any other country, and several hundred are now used. These will deliver the potatoes into bags or into the clamp in a clean condition where the soil is friable and reasonably free from stones. Where, however, the soil is either very wet and sticky, or there are many clods or stones, existing complete harvesters do not put up a satisfactory performance. The R.A.S.E. is this year offering valuable prizes in a potato harvester competition, and it is hoped that this will further stimulate development.

Complete sugar-beet harvesters which top, lift and clean the beet and deliver them either into trailers or in windrows on to the ground have been undergoing development in Britain since the early nineteen thirties, and in the last few years beet harvesting mechanization has made very rapid progress. There are now available, in addition to a variety of complete harvesters, a number of simpler machines which do the topping and lifting as separate operations, and these are widely used where small acreages are grown.

Sugar-beet harvesting is proving to be a job which is quite suitable for contract work, and it seems likely that this method of harvesting will steadily become more important, since farmers who grow 20 acres or less account for half of the total crop. The more expensive complete harvesters are more economical in the use of labour than the simpler machines, and many farmers are likely to find contract work preferable to operating their own machines.

The Era of Tractor-Mounted Machines The main trend of mechanization progress is well illustrated by such machines as hydraulically operated manure loaders and tractor-mounted hedge trimmers. A farmer possessing a modern tractor, with built-in hydraulic lift mechanism, has a choice of about a dozen British-made front-mounted tractor loaders, which can be equipped either with a manure bucket

or a variety of other devices, including such things as hay sweeps. The tractor manure loader, in conjunction with a mechanical manure spreader, enables one man to cart and spread manure at a rate of about 3 tons an hour. In place of the arduous work of handling manure with a hand fork, the operator handles the finger-tip control of the tractor's hydraulic mechanism, and so is able to keep up a good rate of work throughout the day.

The hedges of Britain are perhaps one of the most characteristic features of our country scene. Efficient mechanization has necessitated the grubbing out of some of those which served no useful purpose and interfered with field work, but good fences are essential for stock farming, and a good hedge has many advantages. Several firms have recently developed hedge-trimmers which greatly reduce the labour required for keeping hedges in good order, and it now seems certain that mechanization will help to save the useful hedges and to give them the regular trimming that is necessary to keep them stock-proof.

Machinery for Barn and Dairy During the war the emphasis in mechanization was on field machinery to facilitate the growing of crops for direct human consumption, but with flocks and herds now built up to a high level, mechanization of work about the buildings becomes of high importance. Many of the jobs connected with animal husbandry have to be done daily or twice a day, and mechanization of such tasks can be very well worth while.

The most striking change in food preparing machinery has been the increased use of hammer mills. Many of the mills installed have been high-capacity machines suitable for tractor operation, but where electricity is available the small automatic type which can be left to run unattended has many advantages. Milking machines are now being used successfully with herds of under 10 cows, and a recent study* of their use for such small herds confirms that such equipment can easily justify the installation and running costs.

Farm Transport Transport of one kind or another accounts for a high proportion of the work on most British farms, for in addition to work such as hauling manure, and carting crops, most of the work involved in the day-to-day feeding and care of livestock involves transportation. Use of farm tractors for transport work is steadily increasing, and the efficiency of tractors for such work has been greatly improved by the development of good hydraulic tipping trailers. Two-wheeled trailers are much more commonly used than four-wheeled, and in this respect British farming differs from that of the continent of Europe and from that of North America, where four-wheeled trailers predominate. For light tractors, the unbalanced two-wheeled trailer, which spreads the load between the wheels of the tractor and trailer, is a great advantage, especially when a handy mechanism for picking up the front of the trailer by means of the hydraulic lift mechanism is provided, in addition to a hydraulic tipping device.

Great advances in transportation about the farm buildings can be made by the provision of well-arranged concrete roads and passages, and rubber-tyred feed barrows, etc. On most British farms there is still much room for improvement in this respect.

Some of the types of machines referred to in this article are illustrated on pp. vi–vii *of the art inset.*

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* Labour Organization in Milk Production, Report No. 32 of the Cambridge Univ. Dept. of Agric. Farm Economics Branch (1949).

THE FIGURES SPEAK FOR THEMSELVES

Below are given a few figures of crop production, livestock population, labour and mechanization on the farms of England and Wales, based on the Agricultural Returns made in June, 1950, together with comparative figures before the war and, in some cases, in 1867, the earliest year for which such figures are available.

CROPS

	1867	1939	1950
		(thousands of acres)	
Total Arable	14,433	8,935	13,949
Total Crops and Grass, including Rough Grazings	(a)	30,184	29,916
Cereals			
Wheat	3,257	1,683	2,398
Barley	2,041	910	1,624
Oats	1,753	1,358	1,835
Mixed Corn	(a)	83	827
Potatoes	335	454	866
Sugar Beet	—	337	419
Temporary Grass	2,779	2,104	3,559
Permanent Grass	11,018	15,709	10,496
Rough Grazings	(a)	5,541	5,471
Small Fruit	(a)	47	51
Orchards	(a)	254	273
Vegetables (excluding potatoes) grown in the open	(a)	248	490
Crops grown under glass	(a)	3	5
Flowers	(a)	24	23
Hops	64	19	22

LIVESTOCK

	1867	1939	1950
		(thousand head)	
Cows and heifers in milk	1,656	2,255	2,448
Cows in calf but not in milk		392	503
Total Cattle	4,014	6,770	8,014
Sheep and Lambs	22,025	17,986	12,376
Pigs	2,779	3,515	2,212
Poultry	(a)	56,426(b)	65,312
—of which :			
Fowls		52,912	61,512
Ducks		2,237	2,246
Geese		584	801
Turkeys		693	753
Horses for agricultural purposes	827(c)	549	289

LABOUR

	1939	1950
	(thousands)	
Regular Workers		
Male	471	523
Female	40	52
Total	511	575
Casual Workers	96	155

MACHINERY

	1939	1950
Tractors	50,000	259,870
Combine Harvesters	150	10,000
Milking Machines	23,860(d)	69,170
Spraying Machines	4,750	12,220

MILK

	1851	1939	1950
Production (million gallons)		1,453	1,815
Average weekly consumption per person (*pints*)	1¾	3	5

(a) Not available.
(b) It is estimated that some 3 to 4 million should be added to cover poultry on holdings not recorded until 1941.
(c) 1870.
(d) 1942

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Selected by F. C. Hirst, F.L.A.
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Soils, their origin, constitution and classification. 3rd ed. Robinson, Gilbert Wooding. Murby, 1949. 32s.

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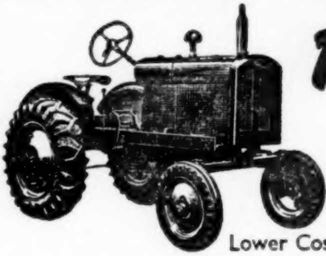

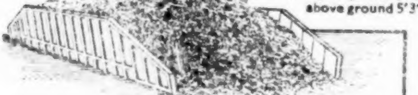

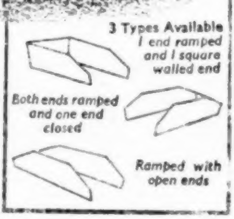
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